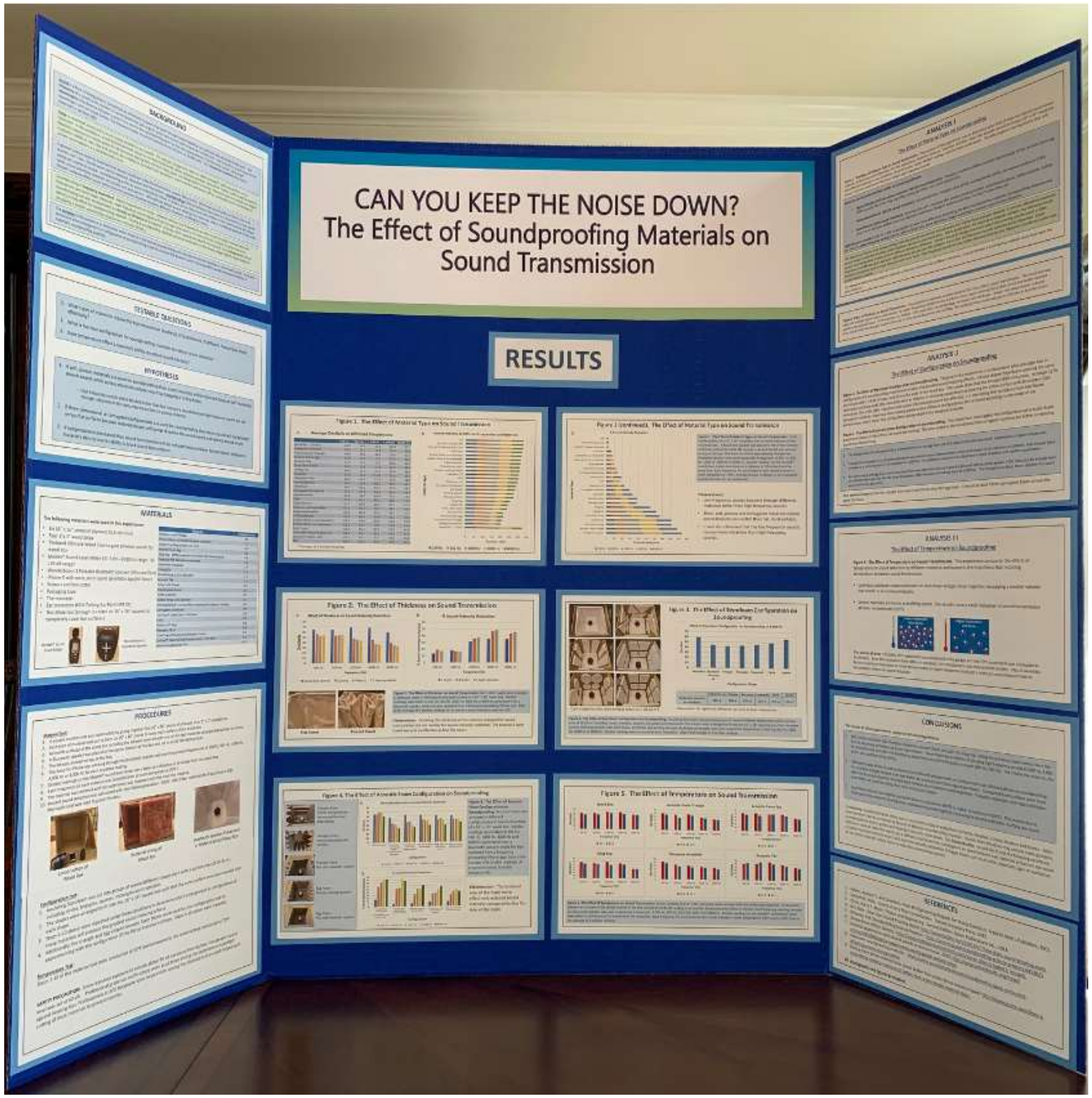
CAN YOU KEEP THE NOISE DOWN?
The Effect of Soundproofing Materials on Sound Transmission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RESULTS

Materials on Display

BACKGROUND

Sound is a form of energy that is transmitted as vibrations or waves that travel through matter reaching our eardrums and perceived by the brain. The **frequency** of a sound is the number of sound waves that pass a given point each second and is measured in hertz (Hz). High frequency sounds have shorter **wavelengths** (the distance between a point on a wave to the corresponding point on the next wave) whereas low frequency sounds have longer wavelengths and can travel further. The frequency range of human hearing is from 20 hertz to 20,000 hertz. The **intensity or loudness** of a sound is measured in decibels (dB).

Noise is unwanted sound and is an increasing problem in our society. For example, background noise can affect a student's ability to perform in the classroom. In the workplace, sound levels have been shown to increase stress levels, blood pressure and heart rates which impact health as well as memory. Repeated exposure to sounds above 85 dB can cause hearing loss and loud noise above 120 dB can destroy hearing. Excessive noise in hospitals can impact a patient's ability to rest, heal and recover and is linked to increased pain sensitivity. Even in doctor and lawyer offices, unwanted sound transmission of private conversations is a confidentiality issue.

Engineers reduce noise by materials that absorb sound and make the environment quieter. Many factors affect how sound travels and how much noise reaches one's ears. Sound waves can be reflected, absorbed and transmitted. **Soundproofing** is the modification of a room or compartment so that sound waves are unable to escape. Soundproofing works by using materials to reduce or absorb sound. Since hard, flat surfaces reflect sound and do not reduce noise, sound absorbing materials are usually soft and porous. Soft materials absorb sound, while porous materials reduce sound by trapping it in tiny holes. Smooth surfaces reflect sound while textured surfaces disperse sounds in different directions, muffling the sound.

Soundproofing is **frequency dependent**. Higher frequencies are better reflected whereas low frequencies are able to pass through a barrier since low frequencies can travel longer distances. High-frequency sound waves are lost through reflections in the many internal surfaces in porous materials. Soundproofing can also be dependent on **density or thickness** of a material. A dense, thick material will absorb more sound. Since **temperature** affects density, it may affect the soundproofing material. Cooling a soundproofing material can cause molecules to slow down and get slightly closer together, occupying a smaller volume that results in an increased density.

The **purpose** of this project is to determine which material is the best at soundproofing and reducing the decibel readings of transmitted sound. It will also determine what arrangement or configuration of soundproofing materials produce the greatest sound-reducing effects and if temperature affects a material's soundproofing qualities.

TESTABLE QUESTIONS

1. What types of materials reduce the transmission (or loudness) of soundwaves of different frequencies most effectively?
2. What is the best configuration for soundproofing materials to reduce sound intensity?
3. Does temperature affect a material's ability to reduce sound intensity?

HYPOTHESES

1. If soft, porous materials are used for soundproofing then sound intensity will be reduced because soft materials absorb sound, while porous materials reduce sound by trapping it in tiny holes.

   - High frequency sounds will be blocked better than low frequency sounds because high frequency sounds are lost through reflections in the many internal surfaces in porous materials.

2. If three dimensional or corrugated configurations are used for soundproofing then more sound will be blocked versus flat surfaces because textured shapes will better disperse the sound waves and reduce sound levels.
3. If temperature is decreased then sound transmission will be reduced because lower temperatures increase a material's density and its ability to block sound transmission.

MATERIALS

The following materials were used in this experiment:

- Six 16” x 16” pieces of plywood (0.5 cm thick)
- Four 1”x 1” wood strips
- Titebond Ultimate Wood Glue to glue plywood panels for wood box
- Mestek® Sound Level Meter (31.5 Hz – 8,000 Hz range; 30-135 dB range)
- Wonderboom 2 Portable Bluetooth Speaker (Ultimate Ears)
- iPhone X with sonic pitch sound generator app (Hz Sonic)
- Scissors and box cutter
- Packaging tape
- Thermometer
- Ear protection (HDX Folding Ear Muff NPR 23)
- Test Materials (enough to create six 16” x 16” squares to completely cover box surfaces)

Mestek® Sound Level Meter

Wonderboom 2 Bluetooth Speaker

Material	Thickness (cm)
Acoustic Foam Triangle	7.5
Pink EcoTouch Unfaced Fiberglass Insulation	5.0
Airspace packing bubble 18 x 6 cm	5.0
Acoustic Foam Egg	4.5
Shag Rug - 100% polyester microfiber with latex backing	4.0
Foamular XPS extruded polystyrene	2.4
Styrofoam Insulation	1.7
Ceiling Tile	1.4
Bubble Wrap 2.5 cm diameter	1.4
Acoustic Tile	1.0
Terry Cloth Towel	0.5
Polyethylene Plastic	0.5
100% polyester	0.5
Bubble Wrap 1 cm diameter	0.5
Moving Blanket – cotton blend padding with polyester binding	0.4
Corrugated Cardboard	0.4
ConTact® Cubed Liner - PVC vinyl	0.4
Cork	0.3
Felt Eco-fi® fiber	0.3
Fiberglass Cloth	0.2
Craft Foam (Polyethylene Standard Foam)	0.2
ConTact® Textured Grip Premium Liner – PVC vinyl	0.2
Heavy Duty Aluminum Foil	< 0.1

PROCEDURES

Material Test:

1. A square wooden box was constructed by gluing together five 16” x 16” pieces of plywood onto 1” x 1” wood strips.
2. Each type of material was cut to form six 16” x 16” pieces to cover each surface of the wood box.
3. All inside surfaces of the wood box including the lid were covered with one of the test materials using packaging tape to secure.
4. A Bluetooth speaker was placed in the center bottom of the box and set to 80 dB reading in air.
5. The lid was secured on top of the box.
6. The Sonic Hz iPhone app working through the Bluetooth speaker was used to generate frequencies of 100 Hz, 500 Hz, 1,000 Hz, 4,000 Hz or 8,000 Hz for each separate reading.
7. Decibel readings on the Mestek® sound level meter were taken at a distance of 10 inches from the wood box.
8. Each frequency for each material was tested 6 times at room temperature (70ºF).
9. The material was removed and the experiment was repeated with the next test material.
10. Percent sound reduction was calculated with the following equation: 100% - (dB of test material/dB of wood box x 100). Microsoft Excel was used to graph the data.

Construction of Wood Box

Material Lining of Wood Box

Bluetooth Speaker Placement in Material Lined Wood Box

PROCEDURES (CONTINUED)

Configuration test:

1. Insulating Styrofoam was cut into groups of several different shapes each with a surface area of 28.26 in^2, including circles, triangles, squares, rectangles and trapezoids.
2. The shapes were arranged to fit into the 16” x 16” square box such that the same surface area was covered with each shape.
3. Steps 4-10 above were repeated under these conditions to determine which arrangement or configuration of these materials will produce the greatest sound-reducing effects.
4. Additionally, the triangle and egg-shaped acoustic foam blocks were used for the configuration test by experimenting with the configuration of the flat or textured surfaces. Steps 4-10 above were repeated.

Temperature Test:

Steps 3-10 of the material test were conducted at 55^{o}F and compared to the material test conducted at 70^{o}F.

SAFETY PRECAUTION: Since repeated exposure to sounds above 85 dB can cause hearing loss, the speaker sound level was set at 80 dB. Professional grade ear muffs where worn at all times during the experiments to protect against hearing loss. Professionals at ACE Hardware store helped with sawing the plywood and an adult helped with cutting of thick materials to prevent injuries.

Figure 1. The Effect of Material Type on Sound Transmission

A. Average Decibels at Different Frequencies

	100 Hz	500 Hz	1,000 Hz	4,000 Hz	8,000 Hz
Wood Box - Control	64.9	64.6	69.1	68.4	59.1
Fiberglass Insulation	47.9	52.2	36.4	35.5	30.8
Acoustic Foam Triangle	49.8	49.6	40.5	38.6	32.4
Acoustic Foam Egg	51.9	53.3	37.7	39.6	36.5
Acoustic Tile	51.9	53.3	37.7	39.6	36.5
Terry Cloth Towel	56.2	53.1	47.4	44.2	38.4
Ceiling Tile	64.6	54.0	45.6	40.8	38.6
Shag Rug	57.3	53.9	57.86	52.8	33.8
Fiberglass Cloth	58.1	63.9	52.4	53.8	48.0
Moving blanket	59.8	53.4	60.7	56.7	45.9
Styrofoam	58.7	60.4	64.7	55.9	44.5
Corrugated Cardboard	53.9	65.4	64.9	56.6	48.3
Aluminum Foil	56.6	54.7	69.9	62.4	54.3
Cork	60.8	61.2	66.1	58.3	57.7
Foamular XPS	61.7	68.0	66.5	62.7	47.2
Airspace packing bubble	61.1	60.2	70.1	63.3	54.7
Polyethylene platic	63.2	59.0	63.5	64.1	59.7
100% polyester	60.3	64.4	66.0	65.2	58.1
Bubble Wrap 2.5 cm diameter	61.6	64.9	65.9	63.9	58.8
Bubble Wrap 1 cm diameter	63.1	58.4	70.6	65.9	62.4
Craft Foam	58.9	66.2	67.2	67.8	63.5
ConTact® Textured Grip Liner	66.4	68.8	66.9	68.0	58.0
ConTact® Cubed Liner	63.1	64.5	67.7	69.5	65.0
Felt	65.4	62.3	67.8	70.1	66.3

* Average of 6 decibel readings

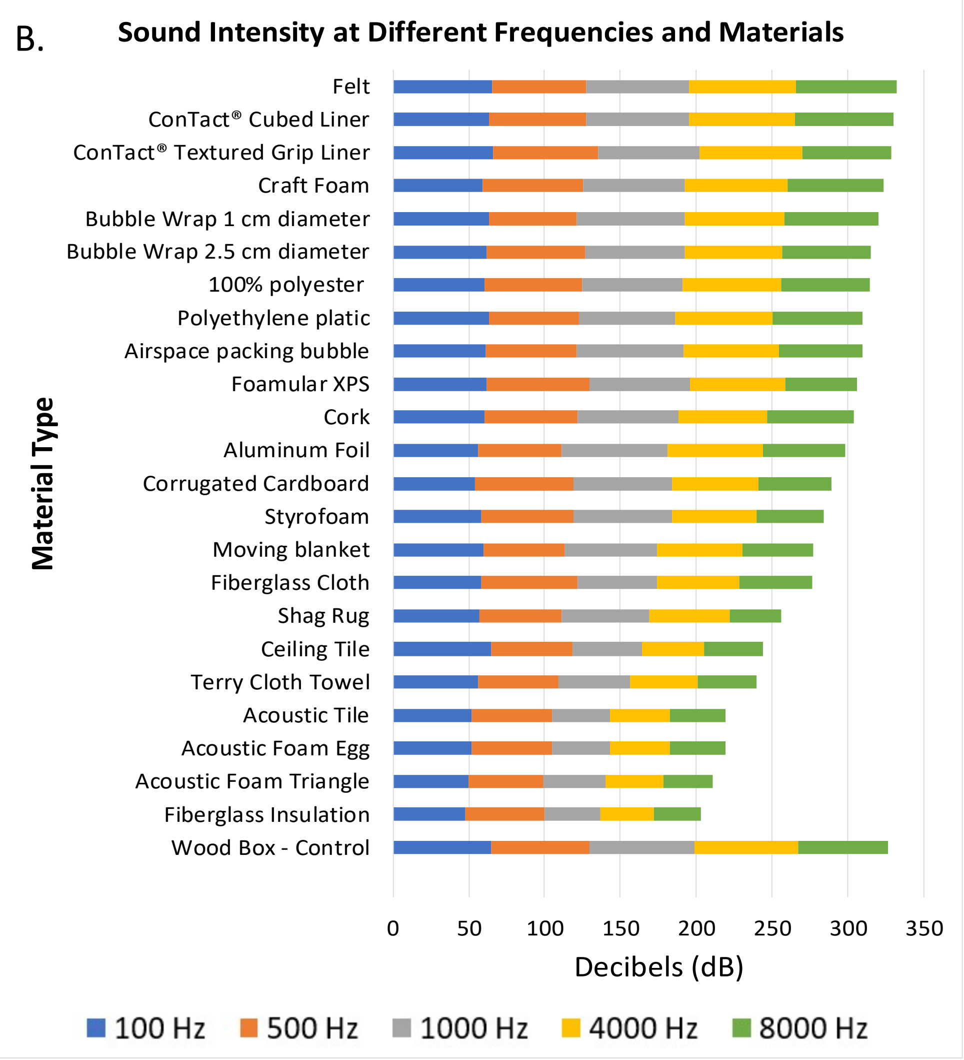


Figure 1 (continued). The Effect of Material Type on Sound Transmission

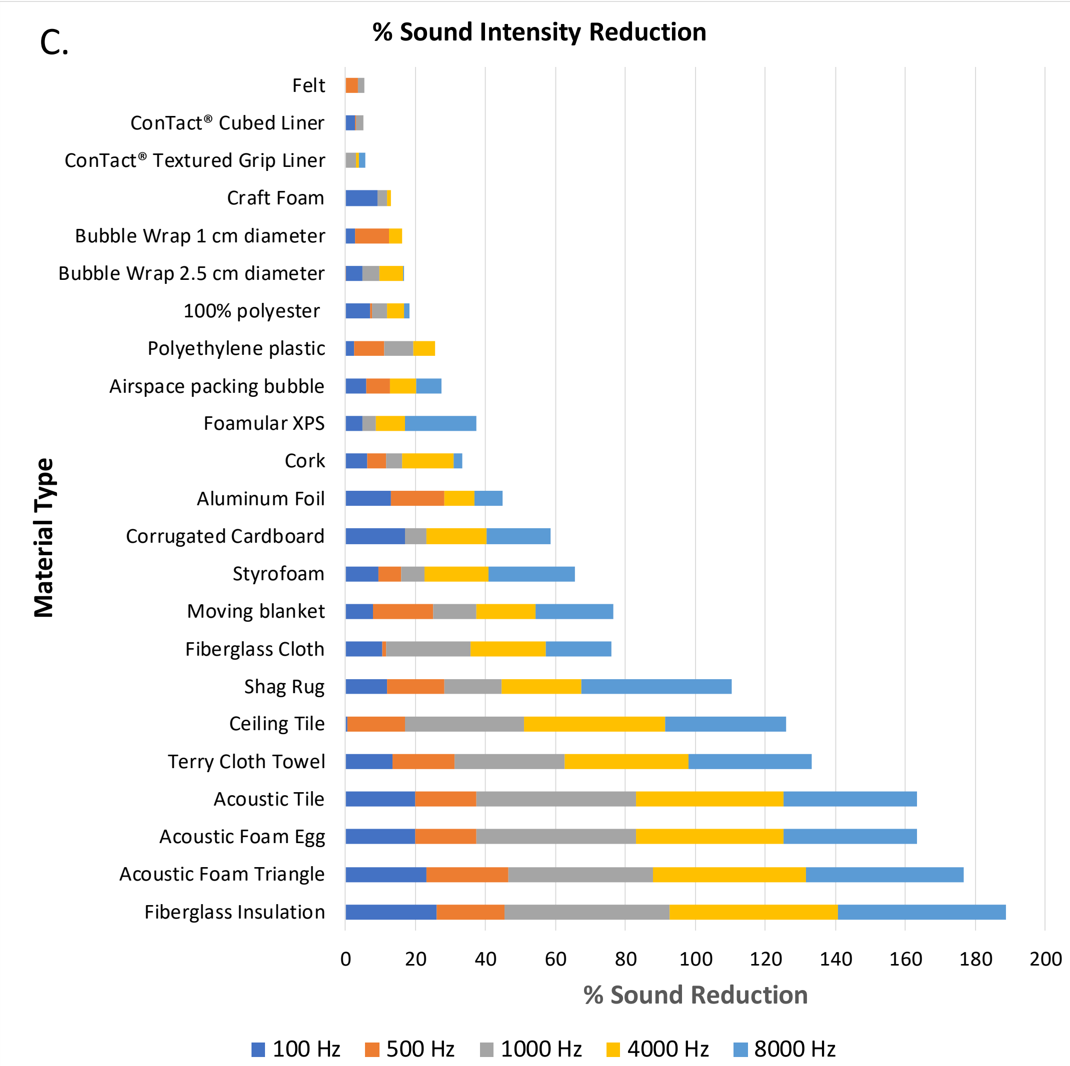
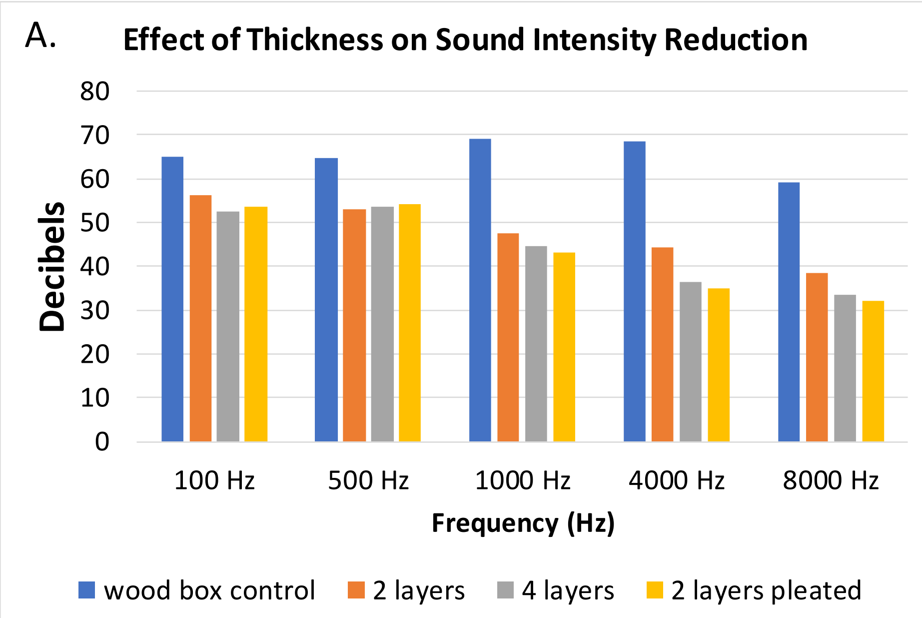


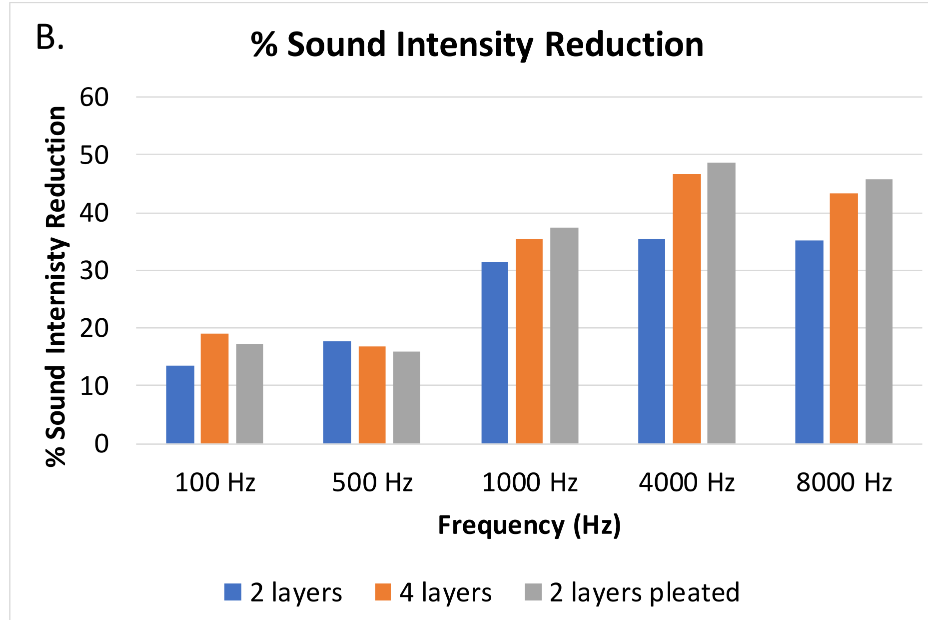
Figure 1: The Effect of Material Type on Sound Transmission. Each inside surface of a 16” x 16” wood box was covered with one of the test materials. A Bluetooth speaker was placed in the center bottom of the box and set to 80 dB reading in air and the lid was secured on top of the box. The Sonic Hz iPhone app working through the Bluetooth speaker was used to generate frequencies of 100 Hz, 500 Hz, 1000 Hz, 4000 Hz or 8000 Hz. Decibel readings on the Mestek® sound level meter were taken at a distance of 10 inches from the wood box. Each frequency for each material was tested 6 times at room temperature (70ºF). Average decibel readings (A, B) or percent sound reduction (C) are presented.

Observations:

- Low frequency sounds transmit through different materials better than high frequency sounds.
- Thick, soft, porous and corrugated materials reduce sound transmission better than flat, hard surfaces.
- It was also observed that the low frequency sounds caused more vibrations than high frequency sounds.

Figure 2. The Effect of Thickness on Sound Transmission





Flat Towel

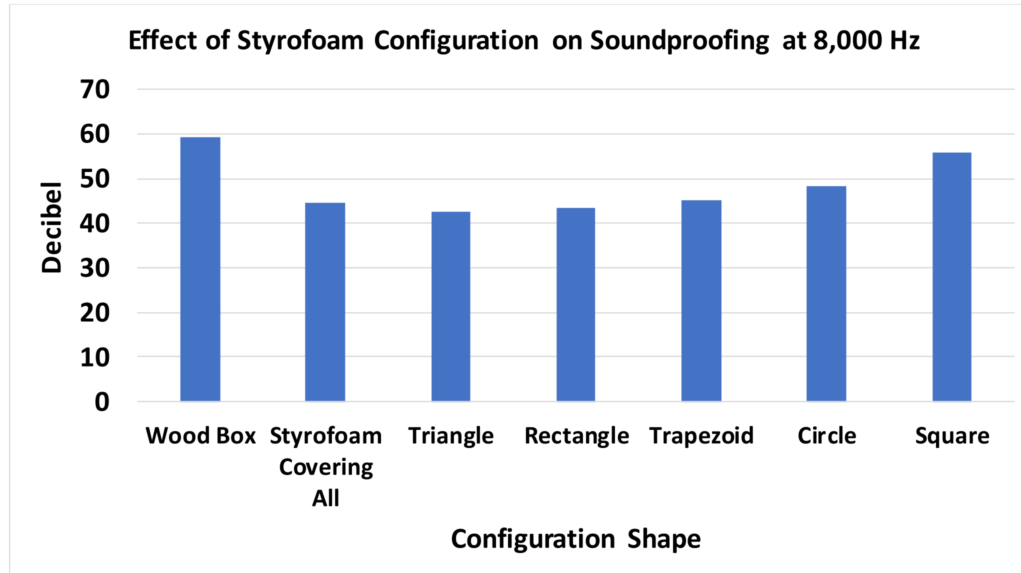
Pleated Towel

Figure 2: The Effect of Thickness on Sound Transmission. Terry cloth towels were arranged in different layers of thickness to line each surface of a 16” x 16” wood box. Decibel readings were taken at 100 Hz, 500 Hz, 1000 Hz, 4000 Hz or 8000 Hz generated from a Bluetooth speaker inside the box operated from a frequency generating iPhone app. Data is the average of 6 decibel readings (A) or percent sound intensity reduction (B).

Observations: Doubling the thickness of the material reduced the sound intensity but did not double the sound intensity reduction. The pleated 2-layer towel was just as effective as four flat layers.

Each shape has the same surface area (SA = 28.26 in^2).

Figure 3. The Effect of Styrofoam Configuration on Soundproofing



	All Styrofoam	Triangle	Rectangle	Trapezoid	Circle	Square
% intensity reduction vs. wood box:	25% ↓	28% ↓	27% ↓	23% ↓	18% ↓	6% ↓

Observation: No significant difference was seen at lower frequencies.

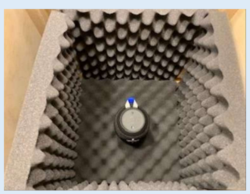
Figure 3. The Effect of Styrofoam Configuration on Soundproofing. Insulating Styrofoam was cut into groups of several different shapes each with a surface area of 28.26 in^2, including circles, triangles, squares, rectangles and trapezoids. The shapes were arranged to fit into the 16" x 16" wood box so that the same surface area was covered with each shape. An iPhone app working through the Bluetooth speaker was used to generate frequencies of 100 Hz, 500 Hz, 1000 Hz, 4000 Hz or 8000 Hz. Decibel readings were recorded at each frequency. Data is the average of 6 decibel readings.

Figure 4. The Effect of Acoustic Foam Configuration on Soundproofing

Triangle Foam
Points facing Speaker
Horizontal/Vertical
Alternating

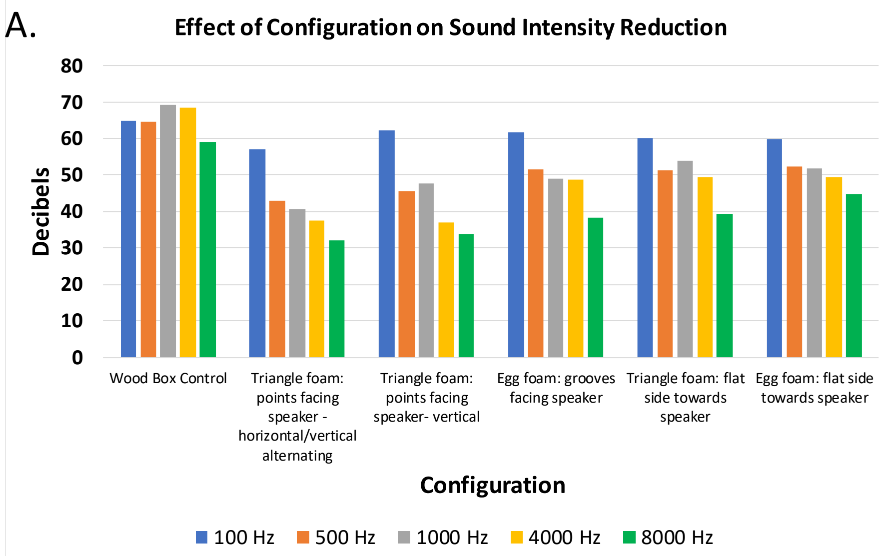
Triangle Foam
Points facing Speaker
Vertical

Triangle Foam
Flat side towards speaker



Egg Foam
Grooves facing speaker

Egg Foam
Flat side towards speaker



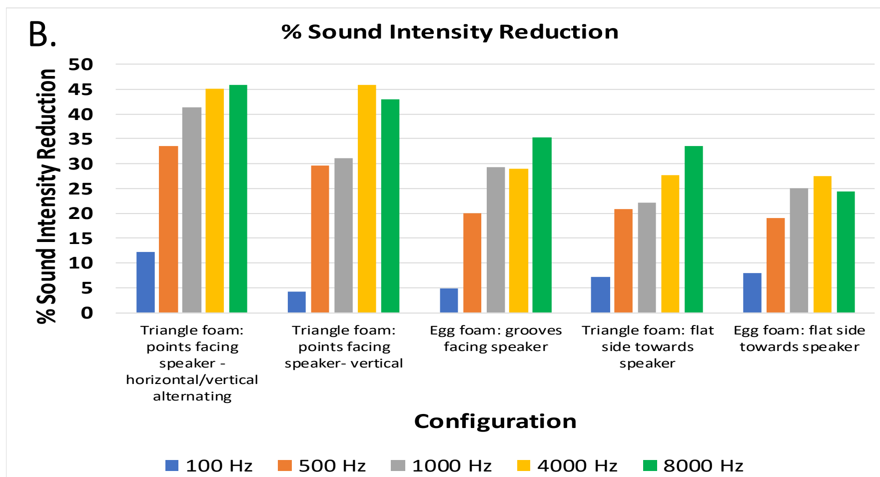


Figure 4. The Effect of Acoustic Foam Configuration on Soundproofing. Acoustic foam was arranged in different configurations to line each surface of a 16" x 16" wood box. Decibel readings were taken at 100 Hz, 500 Hz, 1000 Hz, 4000 Hz and 8000 Hz generated from a Bluetooth speaker inside the box operated from a frequency generating iPhone app. Data is the average of 6 decibel readings (A) or percent sound intensity reduction (B).

Observation: The textured side of the foam more effectively reduced sound intensity compared to the flat side of the foam.

Figure 5. The Effect of Temperature on Sound Transmission

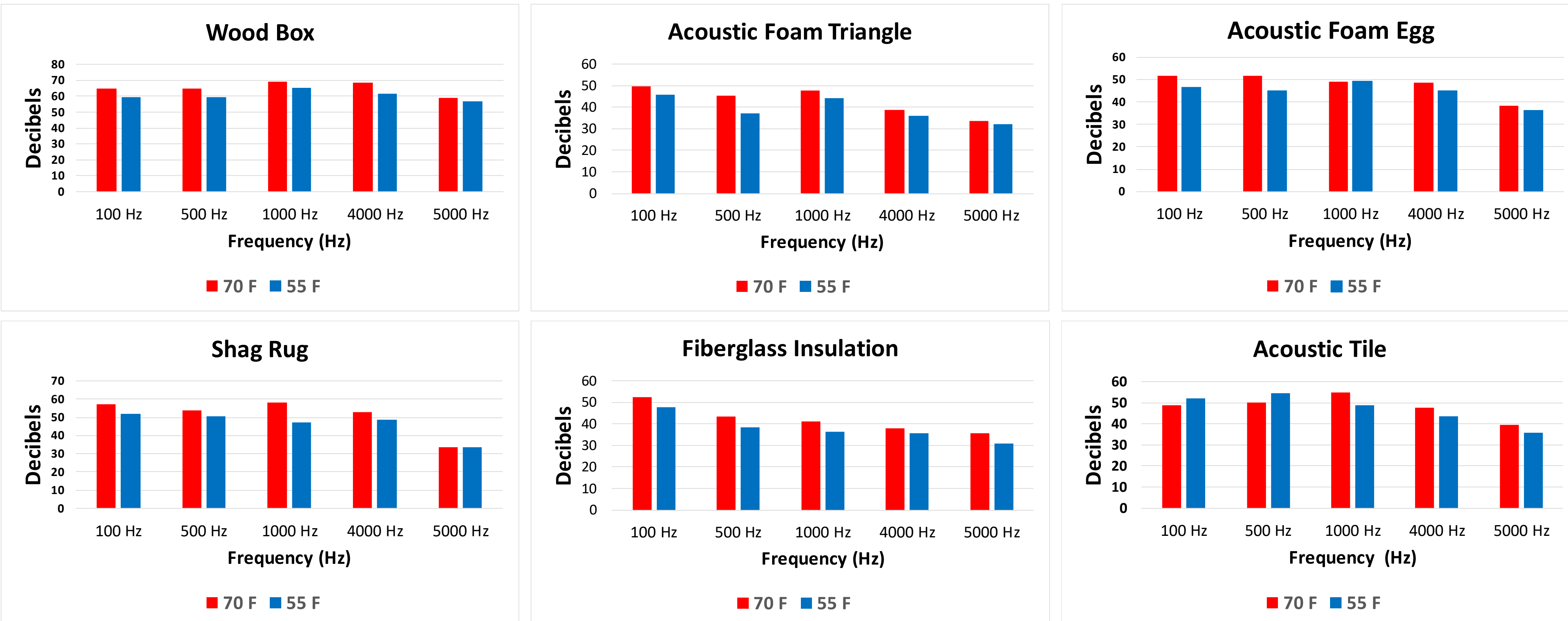


Figure 5. The Effect of Temperature on Sound Transmission. Inside surfaces of a 16” x 16” wood box were covered with one of the test materials. A Bluetooth speaker was placed in the center bottom of the box and set to an 80-dB reading in air and the lid was secured on top of the box. An iPhone app working through the Bluetooth speaker was used to generate frequencies of 100 Hz, 500 Hz, 1000 Hz, 4000 Hz or 8000 Hz. Decibel readings on the Mestek® sound level meter were taken at a distance of 10 inches from the wood box. Each frequency for each material was tested 6 times at room temperature (70ºF) and at 55ºF. Data is the average of 6 decibel readings.

ANALYSIS I

The Effect of Material Type on Soundproofing

Figure 1. The Effect of Material Type on Sound Transmission. The purpose of this experiment was to determine what kind of materials absorb sound waves of various frequencies more effectively. For this experiment, I tried to create an "anechoic chamber" (one that absorbs sound) by lining a 16" x 16" wood box with different materials to see which best reduced sound. Lower decibel readings indicate lower noise levels. The data supports the hypothesis that soft, porous materials would most effectively reduce high frequency sounds.

Materials can be ranked for their ability to reduce sound levels:

- **Highly effective, soft and porous materials (40-58% sound reduction):** fiberglass insulation (48%), acoustic foam triangle (45%), acoustic foam egg (45%), acoustic tile (45%), shag rug (43%), ceiling tile (40%), terry cloth towel (35%)
- **Moderately effective (18-25% sound reduction):** Styrofoam (25%), fiberglass cloth (24%), moving blanket (22%), corrugated cardboard (18%)
- **Non-effective (<15% sound reduction):** aluminum foil, cork, Foamular XPS, airspace packing bubble, polyethylene plastic, 100% polyester, bubble wrap 2.5 cm diameter, bubble wrap 1 cm diameter, craft foam, ConTact® textured grip liner, ConTact® cubed liner, felt

High frequency sounds (1,000 Hz, 4,000 Hz and 8,000 Hz) were more effectively blocked by the best sound proofing materials. Soundproofing materials had less effect on **lower frequency sounds** (100 Hz, 500 Hz) which have more vibrations, longer wavelengths and can travel further distances.

This data shows that the best soundproofing materials are soft and porous. Sound travels into soft surfaces and gets reduced. In porous, absorptive materials, sound energy is converted into heat which disperses and decays the sound wave. When sound waves hit textured or irregular surfaces, the vibrations break up and travel along many smaller paths in different directions (diffusion). Sound is forced to change directions when encountering another pore or fiber. Absorption and diffusion work well with high frequency sounds since the vibration is less than low frequency sounds and more easily dispersed. Lower frequency sounds can push through materials with more force. High frequency sounds are also better reflected whereas low frequency sounds are better able to pass through a barrier.

One **source of error** in comparing the materials is that each material had a different thickness. It would be best if each testing material could have been the same thickness.

Figure 2. Effect of Thickness on Sound Transmission. This experiment examines whether material thickness affects sound transmission. The wood box was lined with multiple layers of terry cloth towels. At higher frequencies (4,000 Hz and 8,000 Hz), more layers covering the surface of the box better reduced sound transmission (4 layers = 47% reduction vs. 2 layers = 35% reduction). Sound blockage increased with thickness. Towels that were pleated reduced more sound (49%) than flat towels (35%) due to more sound dispersion and muffling. The pleated 2-layer towel was just as effective as four flat layers.

ANALYSIS II

The Effect of Configuration on Soundproofing

Figure 3. The Effect of Styrofoam Configuration on Soundproofing. The goal of this experiment is to determine what arrangement or configuration of a soundproofing material will produce the greatest sound reducing effects. Various shaped Styrofoam covering the same surface area (SA = 28.26 in^2) was used to line the walls of the wood box. The results show that the triangle (28% reduction), rectangle (27% reduction) and trapezoid (23% reduction) were as effective in reduce sound levels as covering the entire surface with Styrofoam (25% reduction). The circle (18% reduction) and square (6% reduction) were less effective.

Figure 4. The Effect of Acoustic Foam Configuration on Soundproofing. This experiment investigates the configuration of acoustic foam panel orientation and the effects on sound dampening. This data supports the hypothesis that corrugated surfaces are better at reducing sound than flat surfaces.

1. The triangle foam (43-46% reduction) is more effective than the egg foam (29-35% reduction) in reducing sound transmission at higher frequencies.
2. Triangle foam arranged in an alternating horizonal and vertical pattern reduced more sound transmission (41% reduction at 1,000 Hz) than triangle foam arranged in a vertical pattern (31% reduction at 1,000 Hz). This is because more sound is dispersed in more directions and muffles sound better.
3. For both triangle and egg foam, more sound reduction was seen when the corrugated or grooved side faced the speaker (45% reduction for triangle foam at 4,000 Hz) than when the flat side faced the speaker (28% reduction for triangle foam at 4,000 Hz). The corrugated surfaces better disperse the sound waves and reduce the sound.

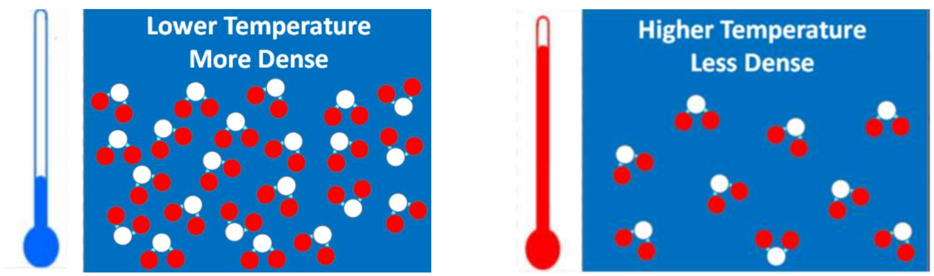
One **source of error** is that the triangle foam was 3 cm thicker than the egg foam. It would be best if both corrugated foams where the same thickness.

ANALYSIS III

The Effect of Temperature on Soundproofing

Figure 5. The Effect of Temperature on the Transmission of Sound. This experiment compares the effects of temperature on sound reduction by different materials and supports the hypothesis that reducing temperature decreases sound transmission.

- Cooling a substance causes molecules to slow down and get closer together, occupying a smaller volume that results in an increased density.
- Denser materials are better at muffling sound. The results show a small reduction in sound transmission at lower temperatures (55°F).



One **source of error** is that the 55°F experiment was conducted in the garage and the 70°F experiment was conducted in the kitchen. Since the two rooms have different acoustics, this introduced a new independent variable. Also, it would be better to perform these tests at lower temperatures or higher temperatures to get a more accurate measurement of temperature effects on sound reduction.

CONCLUSIONS

The results of these experiments supported all three hypotheses.

1. Soft, porous materials (like fiberglass insulation, acoustic foam, acoustic tile, shag rug, ceiling tile and terry cloth towels) were the best at absorbing and reducing sound transmission. These materials are better at blocking high frequency sounds (1,000 Hz, 4,000 Hz, 8,000 Hz) and less effective at reducing sound intensity of low frequency sounds (100 Hz, 500 Hz). The thicker the material, the better the sound proofing ability.

2. Different shapes of the insulating material and different arrangements or configurations had different effects on soundproofing. For example, triangle-shaped foam was better at reducing sound than egg-shaped foam. Corrugated foam surfaces were more effective at sound reduction than flat foam surfaces due to better sound dispersion. Triangles, rectangles and trapezoid shapes were better at sound proofing than circle and square shapes.

3. Sound transmission was slightly reduced at lower temperatures (55^{o}F) vs. higher temperatures (70^{o}F). This may be due to molecules in the material slowing down and becoming closer together, increasing its density and better muffling the sound.

In **summary**, soundproofing has many uses in our society today in workplaces, factories, hospitals, schools, theaters and homes. Many noise problems can be prevented by the use of effective soundproofing materials. Results from this study may provide some guidance on making these spaces quieter and helping to keep the noise down. For **future studies**, I would like to test the following conditions: add more types of materials tested; use a different size/shape box; investigate if air space between two materials or barriers can create a bubble that helps to block sound; and study the acoustic properties of bigger rooms such as at home, classroom, gym or auditorium to see which materials reduce noise to make the surroundings quieter.

REFERENCES

1. Adams, Richard C, and Goodwin, Peter H. Engineering Projects for Young Scientists. Franklin Watts Publishers, 2001.
2. Goldsmith, Mike. Sound: A Very Short Introduction. Oxford University Press, 2015.
3. Olson, Harry F. Music, Physics and Engineering. Second Edition. Dover Publications Inc., 2018.
4. Kivi, Rose. How Does Sound Proofing Work? http://www.hunker.com/13412617/how-does-sound-proofing-work.
5. Devaney, Erik. Soundproofing Science Projects. https://sciencing.com/soundproofing-science-projects-6452623.
6. Temperature Affects Density. http://www.middleschoolchemistry.com/lesson plans/chapter3/ lesson6.
7. Hospital experiments with sound panels to reduce noise. 2015. http://www.uofomhealth.org/news/ archive/201508/hospital-experiments-sound-panels-reduce-noise.
8. Classroom soundproofing products. https://www.soundproofcow.com/soundproof-a-space-restaurant-office/classroom-soundproofing.
9. Does a more dense material stop sound better than a less dense material does? http://www.quora.com/Does-a-more-dense-material-stop-sound-better-than-a-less-dense-material-does.

All photographs and figures by student.