Final Project (Option B): Sound Attenuation

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1 Project Overview

Objective: Investigate the relationship between barrier material properties and sound attenuation, then apply linear regression analysis to model this relationship.

Engineering Context: Sound attenuation is critical in environmental engineering (highway noise barriers), civil engineering (building acoustics), and mechanical engineering (equipment noise reduction). Understanding how materials block sound allows engineers to design effective noise control solutions.

What You'll Learn:
- The relationship between material thickness/density and sound reduction
- Linear regression modeling of experimental data
- Real-world applications in noise control engineering

2 Background: Sound and Decibels

- **Sound Level (dB):** Logarithmic scale measuring sound pressure. Every 10 dB increase represents a doubling in perceived loudness.
- **Sound Attenuation:** The reduction in sound intensity as it passes through a material or barrier.
- **Key Principle — Mass Law:** Sound transmission loss increases with material mass per unit area. Heavier, denser materials generally block more sound.

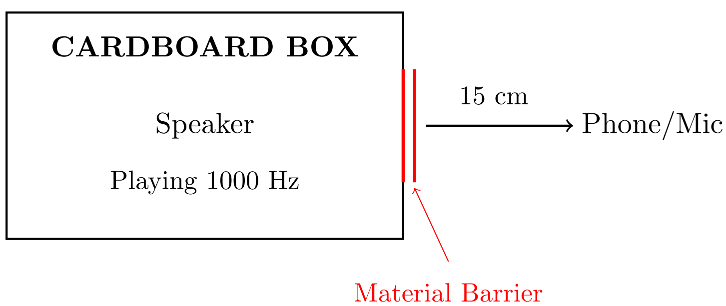
3 Materials & Equipment

Provided by Instructor:
- Cardboard test box
- Bluetooth speaker
- Acoustic foam
- Scissors and tape

Bring Your Own:
- Smartphone with decibel meter app
- Ruler or calipers
- Calculator
- Laptop for data analysis

Important: Download a free decibel meter app BEFORE lab:
- **iOS:** "Decibel X" or "NIOSH Sound Level Meter"
- **Android:** "Sound Meter" or "Decibel X"

4 Experimental Setup



Setup Steps:
1. Place and center speaker inside cardboard box
2. Create an opening in the box for material testing (approx. 10 cm x 10 cm)
3. Set speaker volume to a constant level (do NOT change later)
4. Launch tone generator app on phone (set to 1000 Hz)
5. Install test material over opening (secure all edges with tape)
6. Position phone microphone 20 cm from material surface
7. Start tone generator app (1000 Hz, constant volume)
8. Calibrate: wait 10 seconds for sound stabilization

5 Experimental Procedure

Part 1: Baseline Measurement

1. With NO material installed (open box), measure sound level
2. Take 3 measurements, record all values
3. Calculate average — this is your **baseline**
4. DO NOT change speaker volume for rest of experiment!

Part 2: Distance Testing

1. Select test material and measure its thickness with ruler/calipers
2. Install material, ensuring edges are sealed with tape
3. Wait 5 seconds for sound to stabilize
4. Take 3 sound level measurements
5. Calculate average and sound reduction
6. Layer on next panel to double thickness of material and repeat for next sample
7. Aim to measure sound levels for **at least 10** sample data points (thickness levels)

Critical Controls:
- Keep microphone at same distance for ALL tests
- Keep phone orientation consistent
- Seal material edges completely (no air gaps!)
- Don't change speaker volume between tests
- Test in quiet environment (minimize background noise)

6 Data Collection

Use the template available on the Google Drive to aid this effort. Also record your test conditions.
Test Conditions:
Baseline Sound Level (no material): __________ dB
Test Frequency: 1000 Hz
Microphone Distance: __________ cm
Background Noise Level: __________ dB

Thickness (mm)	Trial 1 (dB)	Trial 2 (dB)	Trial 3 (dB)	Average (dB)
0				

7 Regression Analysis Requirements

For this section, use the Project Python template.

7.1 Create Scatter Plot

Plot **Material Thickness (mm)** on x-axis vs. **Sound Reduction (dB)** on y-axis

- Include all data points from your experiment
- Label axes clearly with units
- Add descriptive title

7.2 Linear Regression Analysis

Calculate the least-squares regression line: $y = \beta_0 + \beta_1 x$ where:

- y = Sound Reduction (dB)
- x = Material Thickness (mm)
- β_0 = y-intercept (baseline)
- β_1 = slope (dB reduction per mm)

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Report the following: • Regression equation: y = _____ + _____ x • Slope:
_____ dB/mm • Y-intercept: _____ dB • Correlation coefficient (r): _____ •
Coefficient of determination (R²): _____
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7.3 Plot Regression Line

Add your regression line to the scatter plot created in step 1

7.4 Residual Analysis

Create a residual plot (residuals vs. predicted values) to check if linear model is appropriate

8 Discussion Questions

Part A: Statistical Analysis *(Answer all questions: Q1–Q5)*

1. Interpret the slope of your regression line. What does it tell you about the relationship between thickness and sound reduction?

2. What is your R^2 value? What percentage of the variation in sound reduction is explained by material thickness?

3. What are the p-values for your slope and intercept? Are they statistically significant at the 0.05 level? Explain what this means in the context of your experiment.

4. Based on your residual plot, is a linear model appropriate for this data? Explain why or why not.

5. Use your regression equation to predict the sound reduction for a 10 mm thick barrier. Is this an interpolation or extrapolation?

Part B: Experimental Design *(Answer Q6)*

6. What were the three most significant sources of error in your experiment? Explain how each could have affected your results and how you minimized them?

Part C: Engineering Applications *(Answer all questions: Q7 AND either Q8 OR Q9)*

7. An office is exposed to 75 dB of outdoor noise. Building codes require interior noise levels below 50 dB. What thickness of acoustic panels/foam would be required? Show your calculation.

8. In real buildings, walls often consist of multiple layers with air gaps (e.g., drywall + air gap + insulation + drywall). Why might this design perform better than a single thick layer? (Research "decoupling" and "resonance")

9. Low-frequency sounds (bass, truck engines) are much harder to block than high-frequency sounds. How might this affect your material recommendations for highway noise barriers vs. HVAC noise control?

Part D: Extra Credit

Option 1: Pad the box with acoustic foam on all sides (except material opening) to reduce reflections. Repeat measurements for one material of your choice. Does this change your results? Explain why or why not.
Option 2: Try a different frequency (e.g., 500 Hz or 2000 Hz). How does frequency affect sound reduction? Discuss implications for real-world noise control.

9 Submission Requirements

9.1 Deliverables

1. Submit a PDF report including:
   (a) **Data Collection (Section 6)** with all measurements
   (b) **Regression Analysis Requirements (Section 7)**
   (c) **Answers to Discussion Questions (Section 8)**

2. Submit a notebook file (e.g., .ipynb) with your regression analysis code

3. Submit your presentation slides as a PDF

9.2 Grading Criteria

- Data collection quality and completeness (20%)
- Regression analysis completeness and correctness (25%)
- Discussion response depth and accuracy (20%)
- Professional presentation (aim for approx 6 slides; 4 minutes): (20%)
  - Organization: Introduction, Data, Methods, Results+Discussion, Conclusion (10%)
  - Quality of graphs and visualizations (5%)
  - Clarity of delivery (5%)
- Code quality and documentation (15%)
- Extra Credit (10% bonus)

10 Additional Resources

Recommended Reading:

- STC (Sound Transmission Class) ratings and building codes
- Mass Law for sound transmission: $TL \approx 20\log(f \times m) - 42$
- OSHA noise exposure standards for workplace safety
- Highway noise barrier design guidelines (FHWA)

Software for Analysis:

- Excel, Google Sheets
- Python, Google Colab