

**ENGR 3030: Sound Demonstration Project**

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Western Michigan University**

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## Introduction

The goal of our project was to demonstrate the effects of sound in a mathematical context for Mrs. Peg Alofs Becker and her students at Kalamazoo Central High School. After discussing different methods of demonstrating sound and its effects, we chose to build an in-class demonstration relating to sound; this demonstration would teach the basic concept of sound and the decibel system, and will demonstrate the relationship between sound intensity and distance.

## Budget

In our final budget, we have spent a total of \$461.35 on our project. The cost breakdown is as follows: the Vernier Sound Level Meter cost \$209, the CBL2 cost \$159.95, and the materials for the box cost a total of \$92.40. The breakdown of material costs for the box can be seen in Table 1. Photographs of the Vernier Sound Meter, the CBL2, and the sound box can be found in Appendix A.

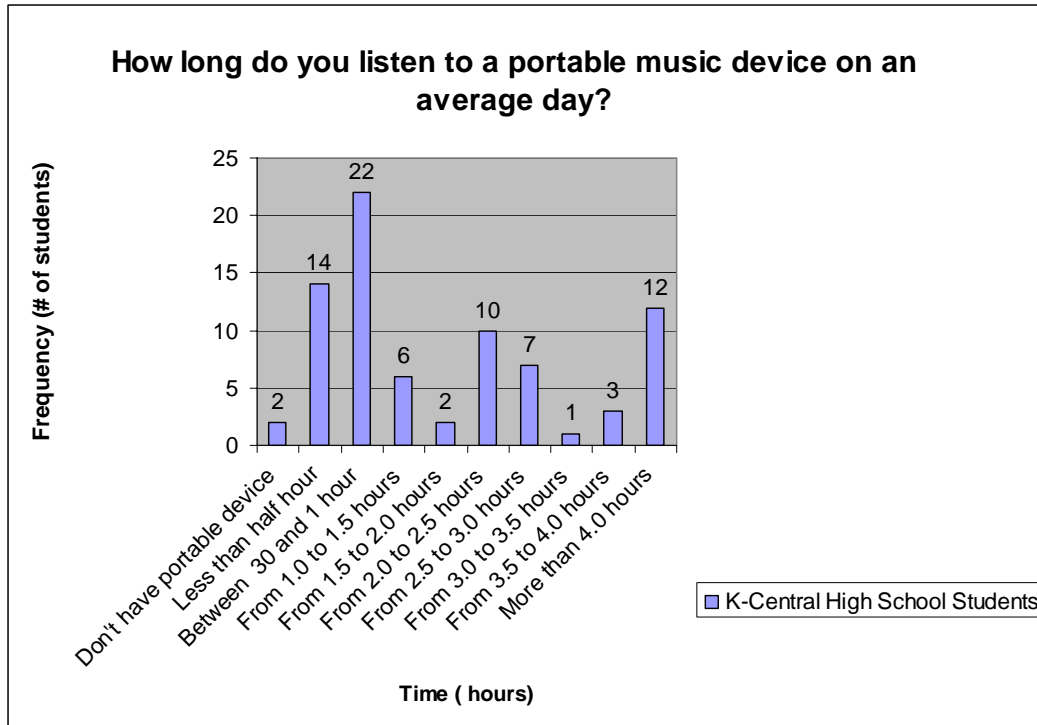
Table 1: Breakdown of Costs in Building the Sound Box

Material	Number	Total Cost
Plexiglass	2	\$36.92
Spray Adhesive	2	\$7.96
Foam Roll	1	\$4.67
Hinges	2	\$2.26
Safety Hasps	1	\$3.86
Handle	1	\$2.44
Plywood	1	\$12.99
Buzzer	1	\$15.45
Board	1	\$5.85
<b>Total</b>		<b>\$92.40</b>

Overall we managed to stay under the budget limit of \$500, mostly due to using less expensive materials and not having to spend any money on making survey copies. Currently we are awaiting reimbursement of capital spent on materials.

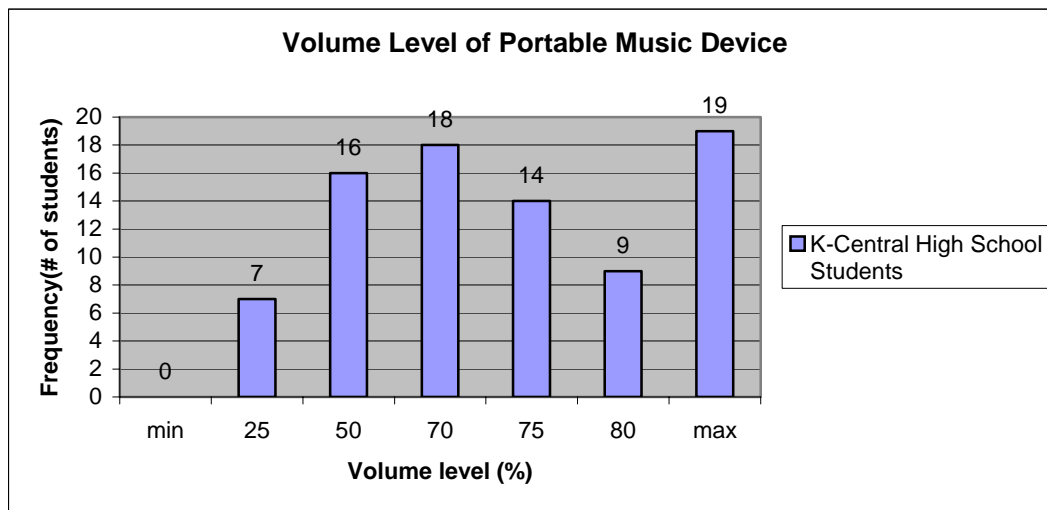
## Survey

As a supplemental part of our demonstration, we distributed surveys to gather data about portable music players and their use by high school students. Thanks to the generosity of Mrs. Peg Becker, we have gathered around 154 completed surveys. A copy of the survey is attached as a reference in Appendix B.



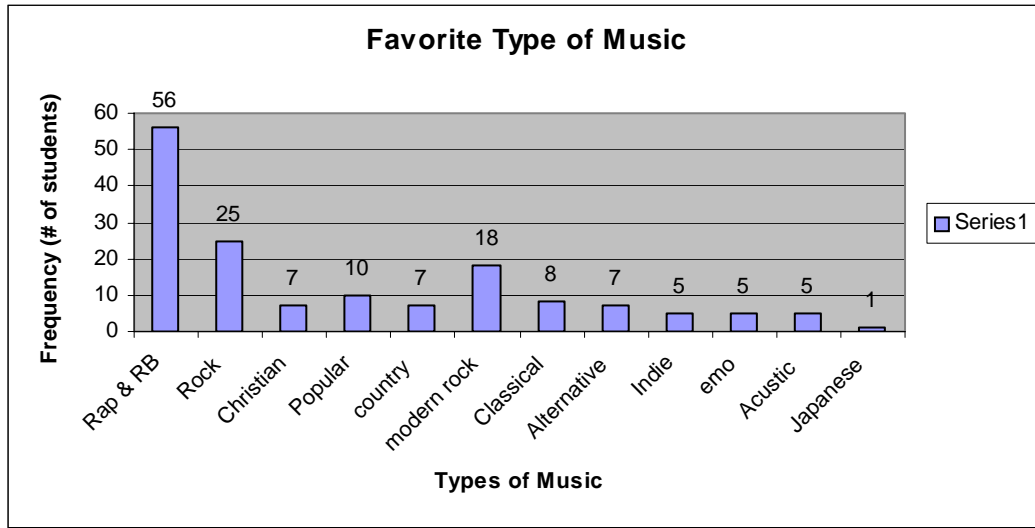
**Figure 1:** Time spent listening to a portable music device

Figure 1 shows that 22 students listen to their music between 30 minutes and an hour per day. This is a pretty good number and is recommended by the apple company, by saying that you should listen to your music for no more than 60 minutes a day or will suffer possible hearing loss down the line. Over 12 students listen to their music for more than 4 hours a day. Of those 12 students, 10 listen to their music for either 5 or 6 hours a day.



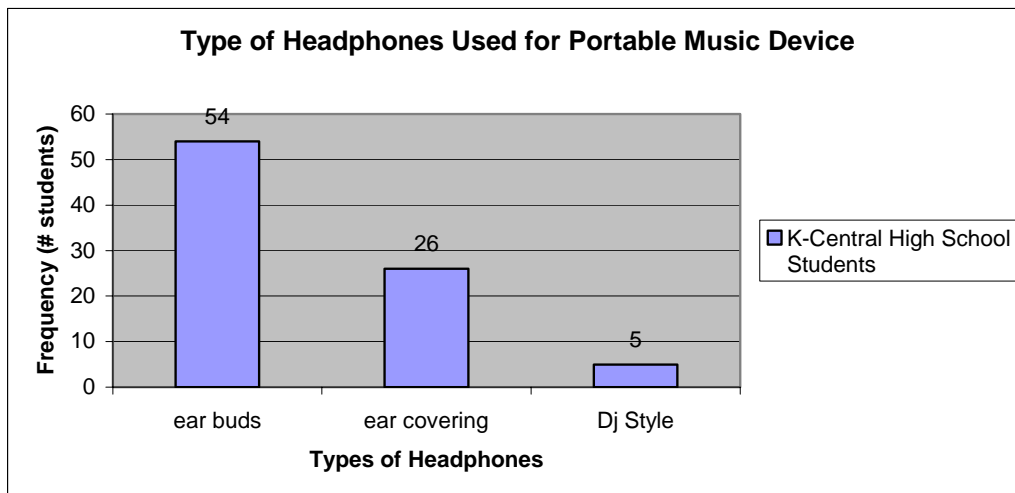
**Figure 2:** Volume Level of Portable Music Device

Figure 2 shows the number of students and the listening volume levels of their portable music device. Based on this data, it can be shown that 19 students have the volume level of their portable music device set at maximum volume level. This is not a surprising number since this generation of students likes to have the whole world listen to their music, mostly in the form of really loud car audio speakers and subwoofers. At the same time, 34 students are listening their music at a volume percentage level of 50 to 70%. Still a high percentage volume level, but a little bit better than listening at the max volume. On the good side, 7 students listen to their music at a volume level of 25%.



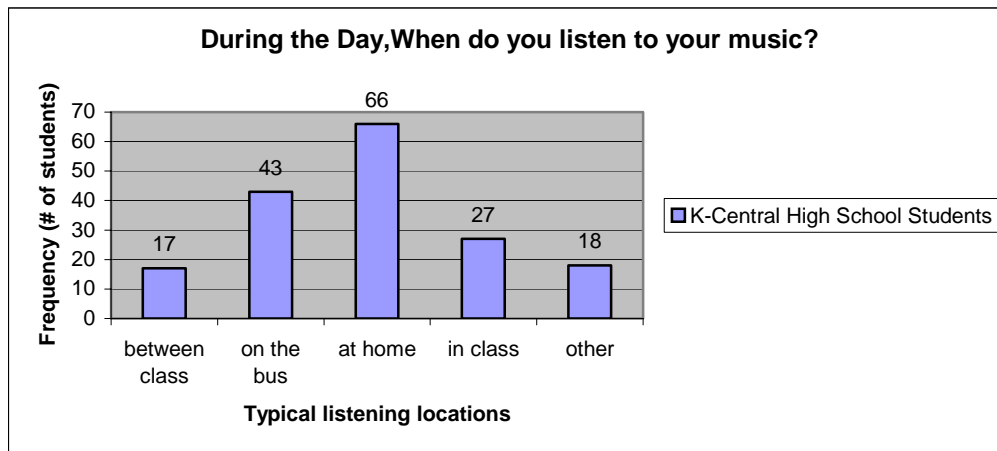
**Figure 3:** Favorite Type of Music for Mrs. Peg Becker’s high school math students

Figure 3 shows the favorite type of music that Mrs. Becker’s high school math students listen to and not surprising is that 56 students listen to rap and R&B music. This music is notorious for having a high base rhythmic type of music, so you would expect that kids would have the volume level set to a high frequency and this is a true fact. On the same note, approximately 43 students listen to rock music. This includes heavy metal, hard rock and classic rock. Still not surprising, because rock music has been apart of our culture since the 50’s and you would expect that a high number of students like rock music.



**Figure 4:** Number of students and their type of headphones for their portable music devices

Figure 4 shows the number of students and the type of headphones they use for their portable music devices. Based on the data, 54 students use ear buds when they are listening to their type of music. The number doesn't again surprise me, since most portable devices today have ear buds. These ear buds are placed directly in the ear and can at some point lead to hearing loss when in fact the volume level is set at a higher frequency.



**Figure 5:** The number of students and the location that they listen to their music the most during a typical school day.

Figure 5 shows the number that a high number of students (66) listen to their music on their portable music devices at home the most than anywhere else during a typical school day. On the same note, 43 students listen to their music on the bus or car before and after school. What does surprise me the most is that 27 students listen to their music during class. I know for a fact that I was not allowed to listen to my music when I was in high school, but I guess that the world has changed and thanks to companies such as apple and Microsoft for these numbers.

## Design Process

In designing our demonstration, we first sat down with Mrs. Becker to see what her requirements would be. We then took her requirements and developed multiple possible projects that fulfilled her requirements. After this, we developed a grading chart that would test to see which project would best suit her needs and our restraints. This decision matrix can be found in Appendix C. Once we found that an in-class demonstration with an associated lecture would best fit the requirements and restraints we began to design the experiment. We knew that we wanted a box that we could look into, so that the students could see the experiment as it progressed. The dimensions of the box were unsure, as well as how we would try to dampen the outside sound. After lots of discussion, we settled on the dimensions of approximately four feet long by a eighteen inches squared as optimal for both storage and experiment size. For foam, we decided on using standard inch and a half insulation board foam, for its ease of use.

## Demonstration

We have completed construction of a 'sound box' that we will be using to demonstrate the effects of sound over distance. We have an experimental procedure for relating sound intensity and distance, thanks to the generosity of Mrs. Becker, and we intend to use its procedure with slight modifications to collect the data we intend to have the students use to see the mathematical relationship. The experimental procedure can be found in Appendix D.

The demonstration starts with an introductory section discussing sound in general. This discussion will cover the topics of how a sound wave travels, the parts of a sound wave, and sound wave expansion. When discussing how the sound wave travels, we looked at how air and other mediums vibrate, and that the vibrations cause waves. These waves then travel to our eardrum and are converted to sound. The part of the sound wave that we covered included the amplitude, frequency, wavelength and period. When discussing amplitude, we pointed out that the amplitude is representative of the energy a wave stores. The frequency determines the pitch of the noise; a high frequency, like a siren, is a high-pitched sound, where as a low frequency, such as a bass, is a low-pitched sound. When discussing sound wave expansion, we looked at sound traveling from a point source and noted that it travels spherically away from the source. Since the surface area of a sphere is  $4\pi r^2$ , we see that as  $r$  increases linearly, the surface increases exponentially. When thinking about sound, and the surface area as sound density, we see that sound density decreases over distance at a rate of the inverse of the distance squared. Since the sound density equates to the sound intensity at that point, we can say that they are one in the same. This led us into our physical demonstrations.

After discussing the general principals relating to sound, we conducted an informal display of sound intensity by having the students speak across the room from the sound meter, and then speak in the same volume while moving closer to the sound meter. As they move closer, the intensity increased. This will provide an initial basis for the experiment, which will be performed next. We will turn on our constant sound source at different distances and record the intensity. This will be performed inside the sound box. Once we had the data, we had the students find the common relationship, and lead them to the conclusion that sound varies to the inverse of the square of the distance away from the sound source. Once they concluded that the closer you get to the sound the louder it becomes, we compared that relationship to the distance between an earbud and the eardrum. We also informed the students of the dangers of high decibels for long periods, as well as common symptoms of hearing loss. Afterwards we opened the room up to questions the students had.

### **Classroom Response**

When getting information about iPod use from the students, we had around 150 responses for analysis. For our in class demonstration, we presented to two classes: Mrs. Becker's Mathematical Modeling Class and her Analysis Class. Both classes contained around 25 students, with around 50 students total that we presented to on November 22, 2006. During the presentation, the students showed surprising attention for the day before a holiday break. The class participated very well with the experiment and lecture, asking many questions about the information. After our demonstration, we felt that the students had an understanding of the material we had presented to them. After speaking with Mrs. Becker a week or two after the demonstration, she mentioned that the students had referenced the information that we had

presented as they moved into their sound unit. This was a very good sign for the retention of the information that we presented. Pictures of us presenting to the class can be found in Appendix A.

### **Static Display**

The static display will be used to display the results of the experiment, as well as provide supplemental information relating to the experimental results and the effects that may occur due to following the patterns seen in the results. The display consisted of four pieces cardboard displaying different information. One displayed the results of the sound versus intensity data. A second piece showed basic decibel levels, and included both the level at which hearing is lost and the level at which an iPod is at maximum volume. The third piece of information is a diagram of the inner ear, showing the entire system; it included data about the amplification of sound as it travels into the ear, as well as the distance from the outer ear to the eardrum, which is about 1 inch. The last display piece showed an article from Apple stating the dangers of hearing loss if the iPod is used to its maximum volume. The display also had a title that could be set up in front of the other pieces, as well as a clear plastic head with earbuds and a fake iPod made out of cardboard. The display showed the connection between earbuds and iPods to hearing loss due to the lack of distance between the eardrum and the earbud.

### **Recommendations**

If a future group were to do something similar to what we have done, we would recommend a few things that they should change. First, we suggest that while presenting to high school students, good visual aides are very important. We also suggest that the box design should be more cubic, if space allows. This would allow for a reduction in the reverberation and reflection of sound within the box, eliminating misleading measurements. The box we designed tended to channel the sound at the meter after seven inches away from the meter. Another recommendation that we can make is to develop a more aesthetically pleasing box. Sound dampening inside the box is recommended as a way to reduce the effect of outside noise on the experiment. Though the box we made did stop some sound from entering, it was not as strong of an effect as we had anticipated. We also recommend that the movement of the sound source be automated in some way so that the box is not required to be opened and closed between each measurement.

### **Conclusion**

The goal of our project was to introduce sound to high school students. We did this through a lab and a lecture. The design and our construction of our box followed a logical design process to ensure that it best met the requirements and constraints on our project. In addition to the lecture and lab, we developed a survey to get information about the use of iPods by the high school students as well as developed a static display that Mrs. Becker could use in the school. Our project succeeded in that the students remembered what we had taught them after we were gone. While we feel good about our project, we realize that there are areas of improvement that our recommendations have addressed.

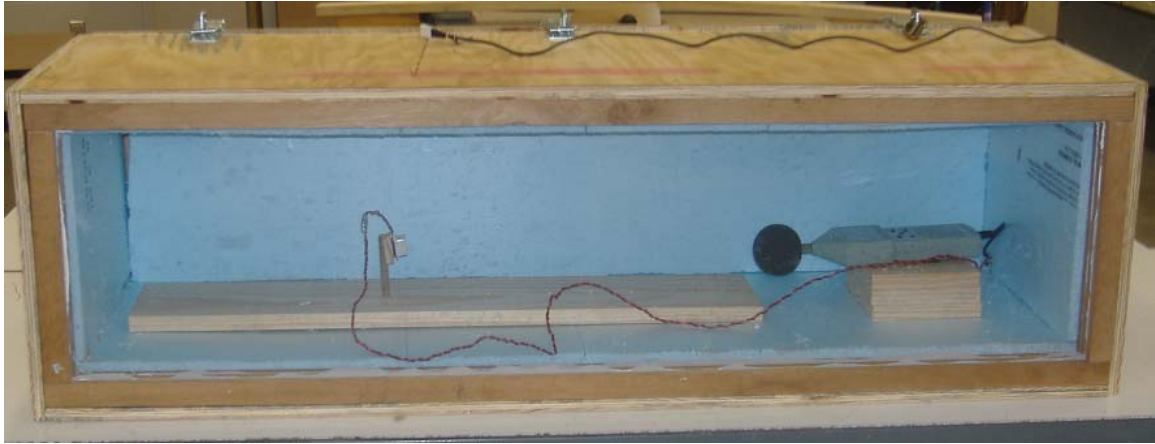
## Appendix A: Pictures



Vernier Sound Level Meter



CBL2 and Accessories



Front View of Sound Box, ready for Experiment



Inside View of Sound Box- Focus on Sound Source



Paul Teaching the Concepts of Sound



Steven and Andy Assisting Two Students in Performing the Experiment

## Appendix B: Survey on Portable Music Device Use

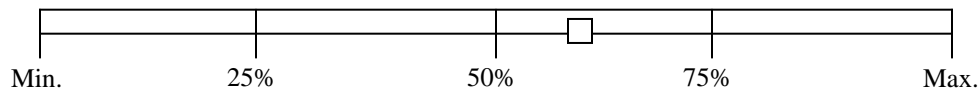
We're doing a survey of how iPods and other portable music devices are used. We'd appreciate your help in this research by sharing your experiences. There are no right or wrong answers; we'd just like your honest response to the questions below. Thank you for your help!

1. On an average day, how much time do you spend listening to a portable music device? (circle)
  - a) I don't listen to a portable music device at all
  - b) Some, but less than half an hour
  - c) Between half an hour and an hour
  - d) From 1 to 1.5 hours
  - e) From 1.5 to 2 hours
  - f) From 2 to 2.5 hours
  - g) From 2.5 to 3 hours
  - h) From 3 to 3.5 hours
  - i) From 3.5 to 4 hours
  - j) 4 or more hours; fill in number of hours: \_\_\_\_\_

2. At what volume level do you listen to music on your portable music device?

On the line below, mark the point **on the line** where you have the volume level set on your portable

music device. For example: you could mark 60% a little right of 50% as shown by the example box.



3. What type of headphones do you use?
  - a) ear buds
  - b) classic ear-covering headphones
  - c) DJ-style ear buds (hint: looks like earmuffs!)
4. What type of music do you listen to the most (rap, country, hard rock, modern rock, classical, etc.)? Please write your responses on the line below.  
\_\_\_\_\_
5. During the day, when do you listen to your music? (circle all that apply)
  - a) between classes
  - b) on the bus / in traffic
  - c) at home
  - d) in class
  - e) other: \_\_\_\_\_

### Appendix C: Decision Matrix

	Budget	Classroom size	Time	Student Participation	Difficulty	Math Relevance	Total
Individual student projects	1	3	3	5	4	5	21
Class Demo	3	4	4	3	4	5	23
Speaker in Water	5	3	4	2	5	1	20
Sound Stations	1	2	3	5	3	5	19

All Constraints Weighted Equally

## Appendix D: iPod Experiment Procedure

### Background Information

- Distance vs. Sound Intensity ( equations)
- Brief lecture on sound (sound as waves, period and amplitude)
- How sound travels
- iPod's and Ear Damage
- Analysis of Class Survey

### Equipment Needed for Experiment

1. One TI-83 or 84 Plus Silver
2. One TI-CBL2

### Experimental Design and Procedure

1. Connect the TI-84 to the CBL using the short link cord
2. Set your calculator in Receive mode using the 2<sup>nd</sup> LINK button
3. Press START and then TRANSFER on the CBL2 **Note:** the CBL2 will automatically transfer the DataMate APPS and PHIDERIVS Program to your calculator. It will beep when it is done. It may take a couple of minutes.
4. Connect the CBL2 to the Sound Meter using CH1 on the side of the CBL2
5. Press the APPS button on the calculator and scroll down to DataMate. If you are using a TI-84, it should automatically decide that you have a sound meter plugged in. **Note:** If you have a TI-83, you will have to press ENTER on CH1 and continue to press ENTER on 7: MORE until you get to the DataMate program.
6. Sound LEVEL (DB): You can now go into SETUP if you want and change the number of samples. Scroll down to MODE:TIME GRAPH and select 2: TIME GRAPH
7. Press START and wait for the data collection to be complete. It will beep and give you a labeled graph.
8. Press ENTER and then 4:ANALYZE and 4:STATISTICS ( You will have to press ENTER on a left bound for the data in the graph you want analyzed, and again ENTER for a right bound on the area of the graph you want analyzed. It should now return the basic statistics for your sound data.

## **Experiment write up**

Graph first 6 data points

Analysis of graph and possible reasons why the graph looks like it does

Discussion of how sound radiates out and reflection of sound