Loudness and decibels – Lab

We are concluding our unit on logarithms. Logarithms are the inverses of exponential functions. Remember that the output of a logarithm is an exponent. For example, $\log_{10}(d) = x$ means that $10^x = d$.

Logarithms are useful when we are dealing with a scale that has a large range of values. By using logarithms, we can take values that are orders of magnitude apart and express them much more closely together.

One such scale is the decibel scale. Decibels are units of measurement we use to measure the loudness of sound, or sound intensity. Below is a table that lists some everyday sounds and their approximate intensity expressed in decibels:

Sound	Intensity (decibels)
Threshold of human hearing	0
Whisper	20
Quiet room	40
Normal conversation	60
Medium truck	80
Jackhammer	100
Rock concert	120
Threshold of pain	130

Note the range between the lowest and highest value in this chart. _________

Before this class, you took several measurements of various sound intensities on campus using a phone application. Along with the measurement of loudness, you noted your own perception of the volume on a scale of 1 -5.

Your professor will provide you with a spreadsheet with the results of this data collection project. In column A you will find a list of all the decibel readings and in column B you will find the corresponding perceptions of loudness for each individual reading.

Take a few moments to examine the data, and answer the following questions:

1. What is the lowest decibel reading that was collected? _______ Where do you guess this reading was collected? _______________________________
2. What is the highest decibel reading that was collected? ________ Where do you guess this reading was collected? _____________________________________
3. What is the range between the lowest and the highest reading that was collected? _________
4. How many total readings were collected by the class? ____________
5. Give a quick impression of that data. Are you surprised by any of the readings that you see collected here, or does this generally match what you would expect?
   ____

Now we are going to organize these data points to get a better picture of what they might demonstrate for us.

1. Highlight both columns A and B.
2. From the drop down INSERT menu, select Chart.
3. Select the chart type: Scatter Chart
4. Arrange the settings for the chart so that the x-axis shows the perceived loudness values (1-5) and that the y-axis shows the decibel readings. You should see five columns with points plotted along five vertical lines.
5. Make sure that each axis has the appropriate label (Perceived Loudness v. Decibels)

Check with your instructor that the chart is set up properly, then answer the following questions:

1. Locate the lowest decibel reading on the chart. What is the perceived loudness value associated with it? _____
2. Locate the highest decibel reading on the chart. What is the perceived loudness value associated with it? _____
3. Are there any points on the chart that seem to be outliers (e.g., a high decibel reading with a low perceived value of loudness)? ____; if there are any, can you hypothesize a reason for these particular data points? ____
4. Do you notice a trend in the data? Do the readings on the chart from left to right seem to follow a particular trajectory? ____

Remember, decibels are useful because they represent a small set of values that can be mapped onto a wide range of intensities**. The relationship between perceived loudness and decibels is a great model for how we actually hear, and it shows up as a linear function, or a straight line**. Can you see the relatively linear path that is suggested by the scatter chart we created?

Using decibels fits our understanding and perception of loudness. To show the usefulness and practicality of the decibel, we are going to convert our decibel measurements back to the original exponential function. Loudness, or sound intensity (noted by the variable I) is measured in watts/m^2. The threshold of human hearing (I_0) is 1×10^{-12}watts/m^2 (that is, $I_0 = 1 \times 10^{-12}$watts/m^2). The formula to convert intensity to decibels is:

$$\text{Number of decibels} = 10 \log_{10} (I/I_0)$$

Remember, I_0 is a constant. If our intensity measurement (I) is also at the threshold of hearing, then the equation becomes:

$$\text{Number of decibels} = 10 \log_{10} (1)$$

$$\text{Number of decibels} = 10 \times 0$$

$$\text{Number of decibels} = 0$$

We can manipulate the original equation to get (*I*) on one side of the equation.

$$I = Io(10)^{\frac{dB}{10}} \text{ where } Io = 1 \cdot 10^{-12}$$

We are now going to convert all the decibel measurements into watts/m^2. To do this quickly, we will set up an equation in the spreadsheet. The equation will convert the decibel readings from Column A into the new value in Column D.

1. In cell C1, type the label Decibel/10
2. In cell C2, type the following formula: =A2/10
3. Copy the cell (formula) and paste it into the remaining cells in Column C.
4. In cell D1, type the label: Sound Intensity
5. In cell D2, type the following formula: `=(10^-12)*(10^C2); click return.`
6. Copy the formula from cell D2 and paste it in the remaining cells in Column D.
7. Following the steps from earlier in the lab, create a Chart that plots Column B (Perceived Loudness) on the x-axis versus Column D (Sound Intensity) on the y-axis. Clicking on the dots in the corner of the Chart allows you to edit the titles and names, if needed.

Check with your instructor that the chart is set up properly, then answer the following questions:

1. What aspects of the data are harder to see in this visualization? You might think about range, trends, etc. ____
2. Which chart is ultimately easier for us to use in understanding the relationship between perceived loudness and volume? ____
3. Look at the data in Column D of the spreadsheet. Do you have any zeroes in the data? If so, why might this be? ____
4. In 2-3 sentences, summarize what you've learned from this lab about the relationship between logarithms and exponential functions <u>or</u> the way in which logarithms can help us model real world concepts?

Bonus question: Can you think of another logarithmic scale that helps us convert a large range of values into a manageable scale? (Hint: A 4 on this scale is mostly minor, while an 8 would be catastrophic.)

Name:

Honor Code: