

INTENSITY OF SOUND

The objectives of this experiment are:

- To understand the concept of sound intensity and how it is measured.
- To learn how to operate a Sound Level Meter

APPARATUS: Radio Shack Sound Level Meter, meterstick, function generator, headphones.

INTRODUCTION

Sound energy is conveyed to our ears (or instruments) by means of a wave motion through some medium (gas, liquid, or solid). At any given point in the medium the energy content of the wave disturbance varies as the square of the amplitude of the wave motion. That is, if the amplitude of the oscillation is doubled the energy of the wave motion is quadrupled.

The common method in gauging this energy transport is to measure the rate at which energy is passing a certain point. This concept involves sound *intensity*. Consider an area that is normal to the direction of the sound waves. If the area is a unit, namely one square meter, the quantity of sound energy expressed in Joules that passes through the unit area in one second defines the sound intensity. Recall the time rate of energy transfer is called "power". Thus, sound intensity is the power per square meter. The common unit of power is the watt (1w = 1 Joules/s).

Normally, sound intensity is measured as a relative ratio to some standard intensity, I_0 . The response of the human ear to sound waves follows closely to a logarithmic function of the form $R = k \log I$, where R is the response to a sound that has an intensity of I , and k is a constant of proportionality . Thus, we define the relative sound intensity level as

$$SL(dB) = 10 \log \frac{I}{I_0}$$

The unit of SL is called the decibel (abbreviated dB). I is the intensity of the sound expressed in watts per meter and I_0 is the reference intensity defined to be 10^{-12} w/m². This value of I_0 is the threshold (minimum sound intensity) of hearing at 1 kHz for a young person under the best circumstances. Notice that I/I_0 is a unitless ratio; the intensities need only to be expressed in the same units, not necessarily w/m².

Examples:

1. If we measured a sound intensity to be 560 greater that the threshold reference, what would be the sound level expressed in dB?

$$SL(dB) = 10\log\left(\frac{560 \cdot 10^{-12}}{10^{-12}}\right) = 10\log(560) = 27.5dB$$

2. The threshold of pain is about 120 dB. How many times greater in intensity (in w/m^2) is this?

$$SL(dB) = 10\log\left(\frac{I}{I_0}\right)$$

$$\frac{120}{10} = 12 = \log\left(\frac{I}{10^{-12}}\right)$$

$$10^{12} = \frac{I}{I_0}$$

$$I = 1 \text{ watt} / m^2$$

Notice that the approximate threshold of pain is a factor of 10^{12} (that's a trillion!) greater than the threshold of hearing.

The Sound Level Meter

The instrument we will use for measuring sound levels is a Sound Level Meter (SLM) shown to the right.* It consists of a microphone to detect the sound and convert it to a voltage, an amplifier to increase this voltage, weighting circuitry which is explained below, and a meter to display the sound level in dB.

The SLM has three switches to control its operation:

Range Selector: The rotary switch is used to select one of seven sound level ranges, each spanning 16 dB. Numbers of RANGE switch refer to the center-points of the seven ranges. The needle indicator shows the actual sound level as a displacement from the center-point.

Examples: Suppose RANGE is set to

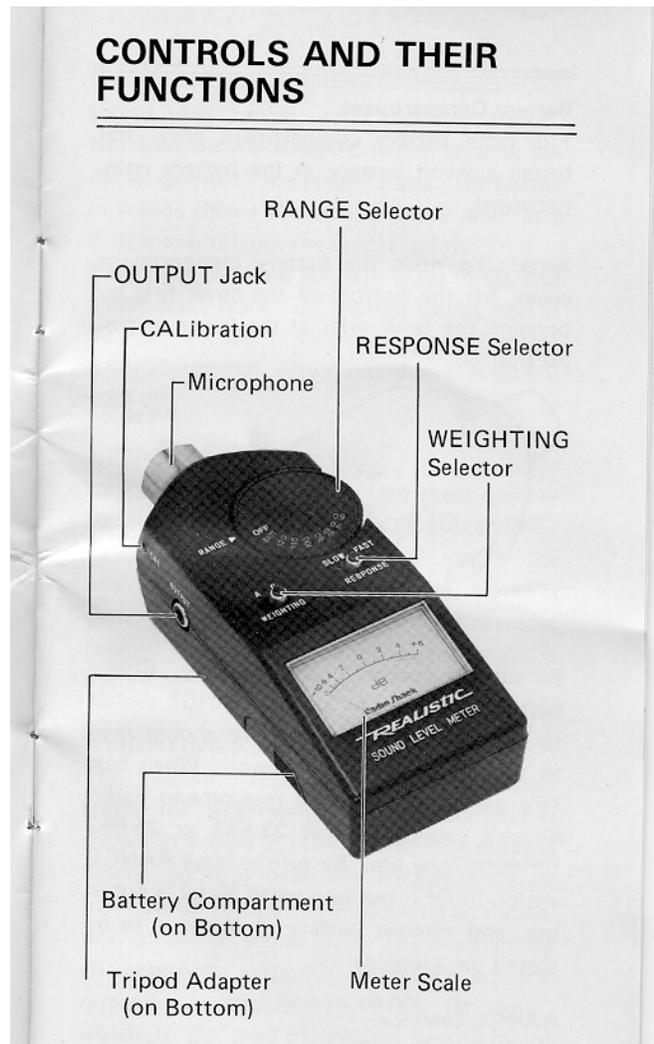


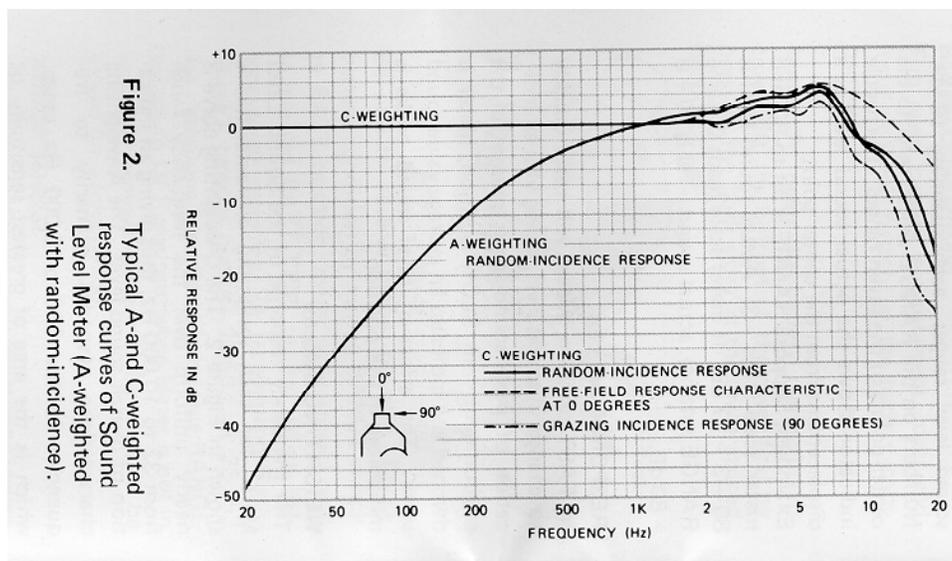
Figure 1

* Adapted from the owner's manual of the Radio Shack Sound Level Meter, ©1985 Tandy Corporation.

80, and meter scale reads -3. Actual sound level is $80 - 3 = 77$ dB. If the meter scale reads 0 (same RANGE setting), the actual sound level is $80 + 0 = 80$ dB.

Response Selector: In FAST position, the meter will react quickly to the change in the sound level, giving you an indication of peak sound levels present in the environment. On SLOW position, the meter is damped and indicates an averaged value for the sound level. The effect of bursts of sounds (intensity peaks) is minimized in the SLOW response.

Weighting Selector: The frequency response of the Sound Level Meter for each weighting characteristic is shown below. The C-weighting curve is nearly uniform over the frequency range from 32-10,000 Hz, thus giving an indication of overall sound level. The A-weighting characteristic responds primarily to frequency ranges in the 500-10,000 Hz range, which is the area of the greatest sensitivity of the human ear.



Taking Accurate Measurements: Select the RESPONSE and WEIGHTING. If the sound source consists of short bursts, or if you are interested in peak values only, set the RESPONSE to FAST. To measure average sound levels, use the SLOW setting. Select A-weighting for noise level determinations, and C-level for measuring sound levels which stay at 90 dB or above, or for which you wish to eliminate the ear's weighting factor.

Start with the HIGHEST RANGE setting (120 dB) and work downward until there is significant deflection of the needle. For GREATEST ACCURACY, always use the lower of any two possible settings.

Example: If the RANGE is set to 80 dB and the meter reads around -5, reset the RANGE to 70 dB and the meter will read +5, for an actual sound level of 75 dB.

The Sone

The decibel is a measure of the sound level which does not include the human perception of loudness. The SONE is a unit that measures the perceived loudness of a sound. It is defined in terms of decibels and frequency:

$$\begin{aligned} 1 \text{ Sone} &= 40 \text{ dB @ 1 kHz} \\ &= \text{the loudness of a 1 kHz sound with a S.L. of 40 dB.} \end{aligned}$$

At 1 kHz, the loudness in Sones can be related to the S.L. in decibels by the following formula:

$$\text{Loudness (Sones)} = 2^{(\text{S.L. in dB} - 40)/10}$$

Example: What is the loudness in Sones of a 50 dB sound

$$\text{Loudness (Sones)} = 2^{(50-40)/10} = 2^1 = 2$$

Sones are useful units in that 2 Sones are twice as loud as 1 Sone and 4 Sones are 4 times as loud as 1 Sone. However, the ear has no meterstick to judge loudness very accurately. The interpretation of the data from the ear is done by the brain, not by a more exact electronic meter. In this part of the experiment, we will try to find out how accurate the Sone scale is.

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LAB REPORT FORM

NAME: _____ DATE: _____

PARTNER(S): _____

Procedure 1:

A. Familiarize yourself with the operation of the Sound Level Meter by measuring the background sound level of the lab room. Turn on the meter by setting the range dial to 120 dB. Set the response of the meter to SLOW and the weighting to C. Measure the background sound level of the room by rotating the weighting to C. Measure the background sound level of the room by rotating the range knob down through the ranges until the meter moves. Also, measure the background sound level using the A weighting of the meter.

Background Sound Level with C weighting = _____

Background Sound Level with A weighting = _____

Calculate the difference between the S.L. measured with the C and A weighting and use the graph (Figure 2) to estimate the average frequency of the background sound.

B. Measure the sound level of a person talking from various distances. you will want to use FAST response to get peak sound levels. This does not have to be quantitatively accurate. Use the meter stick to measure the distances.

Distance ()	Sound Level (dB)

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Question One: What role does distance play in the sound intensity? Explain your conclusions.

Part Two:

Procedure Part Two:

A. Connect the function generator to the headphones. Set the generator to a 1 kHz sine wave. Put the Sound Level Meter microphone next to one earpiece of the headphones and adjust the intensity to 60 dB. The OUTPUT knob on the function generator adjusts the voltage and resulting intensity to the headphones. Also make sure that all of the other knobs are pushed IN and turned fully counter-clockwise (off).

Question Two: as for the Sound Level Meter, which weighting should you use? Why.

Question Three: How many Sones is this? Show your calculation.

Put on the headphones. Now adjust the function generator until the sound is twice as loud. Your calculation should have shown that the original sound is 4 Sones. Now you

have a sound level twice that of 8 Sones. Take off the headphones and measure the sound level in dB using the Sound Level Meter. Repeat your adjustment several times to see how reproducible it is. (Lab partners can try it too.) Now double the loudness again (16 Sones) and measure the sound level in dB. Repeat again for 32 Sones. If the sound is too loud for your ear, STOP! Be careful not to hurt your hearing.

Compare your data to the theoretical prediction that the doubling of loudness in Sones is the equivalent of an increase in loudness by 10 dB. Calculate the percent deviation between the two.

$$\text{Deviation (\%)} = 100\% * ([\text{experimental} - \text{theoretical}] / \text{theoretical})$$

Loudness (Sones)	Theoretical Sound Level (dB)	Measured Sound Level (dB)	Deviation (%)

B. Now set the function generator to 100 Hz sine wave. Set the Sound Level Meter to "A" weighting. Now adjust the loudness from the headphones for 60 dB. Listen Repeat this for 1 kHz. Which signal sounds louder?

Louder signal is: _____

Try repeating this for "C" weighting.

Signal (Hz)	Loudness "A" Weighting (dB)	Loudness "C" Weighting (dB)	Sones - "A" Weighting (Sones)	Sones - "C" Weighting (Sones)
100				
1000				

