

Measurement of Sound Intensity

The decibel was invented by engineers at Bell Telephone as a convenient way to measure sound intensity. The name is in tribute to the company’s founder Alexander Graham Bell. Suppose L represents loudness level in decibels and I represents sound intensity. The following table gives several values.

Sound	Sound Intensity, I (W/cm²)	Loudness Level, L (dB)
Threshold of hearing	0.0000000000000001 = 10^{-16}	0
Normal breathing	0.000000000000001 = 10^{-15}	10
Quiet library	0.0000000000001 = 10^{-12}	40
Busy street traffic	0.000000001 = 10^{-9}	70
Jackhammer (at 2 m)	0.000001 = 10^{-6}	100
Jet plane takeoff (at 30 m)	0.001 = 10^{-3}	130
Rupture of eardrum	1	160

- (1) 1. Given any value of I , we would like to determine how can we find L .
As a start, create a middle column called $X = \log I$.
Fill in the blanks to complete the third column in the table below.

Sound	Sound Intensity, I (W/cm²)	$X = \log I$	Loudness Level, L (dB)
Threshold of hearing	10^{-16}	_____	<u> 0 </u>
Normal breathing	10^{-15}	_____	<u> 10 </u>
Quiet library	10^{-12}	_____	<u> 40 </u>
Busy street traffic	10^{-9}	_____	<u> 70 </u>
Jackhammer (at 2 m)	10^{-6}	_____	<u> 100 </u>
Jet plane takeoff (at 30 m)	10^{-3}	_____	<u> 130 </u>
Rupture of eardrum	1	_____	<u> 160 </u>

- (1) 2. Look at the last two columns, X and L . How can you tell that the relationship is linear? (You might make a column showing ΔX and ΔL and discuss what this tells you.)
- (1) 3. Suppose L is written as a function of X .
Is this function **increasing**, **decreasing**, or **constant**? _____
- (2) 4. If the equation of this function is written in the form $L = mX + b$, what is the value of m ? _____
(This is where the “deci” comes from in the name decibel.) What is the value of b ? _____
Before proceeding, check your equation is correct with a grapher by producing a table which matches the values for X and L above.

Select the best choice for your equation.

- | | | | |
|------------------------------|-------------------------------|--------------------|---------------------|
| A. $L = \frac{1}{10}X$ | F. $L = -\frac{1}{10}X$ | K. $L = 10X$ | P. $L = -10X$ |
| B. $L = \frac{1}{10}X - 16$ | G. $L = -\frac{1}{10}X - 16$ | L. $L = 10X - 16$ | Q. $L = -10X - 16$ |
| C. $L = \frac{1}{10}X + 16$ | H. $L = -\frac{1}{10}X + 16$ | M. $L = 10X + 16$ | R. $L = -10X + 16$ |
| D. $L = \frac{1}{10}X - 160$ | I. $L = -\frac{1}{10}X - 160$ | N. $L = 10X - 160$ | S. $L = -10X - 160$ |
| E. $L = \frac{1}{10}X + 160$ | J. $L = -\frac{1}{10}X + 160$ | O. $L = 10X + 160$ | T. $L = -10X + 160$ |
| | | | U. None of these |

- (1) 5. You have found L in terms of X .
Resubstitute $X = \log I$ in your equation
to write L in terms of I .

$L =$

(An expression involving real numbers and I .)

- (1) 6. If you sit in the front row of a rock concert,
its sound intensity is 10^{-4} W/cm^2 .
What is the loudness level in decibels? _____
Use an equation and show work.

	I	L
Threshold of hearing	10^{-16}	0
Normal breathing	10^{-15}	10
Quiet library	10^{-12}	40
Busy street traffic	10^{-9}	70
Jackhammer (at 2 m)	10^{-6}	100
Jet plane takeoff (at 30 m)	10^{-3}	130
Rupture of eardrum	1	160

Check that your result is you expect, keeping in mind the table of sound intensity measurements.

- (1) 7. The blast of 1 kiloton of T.N.T. is quite loud – about 240 dB. Give its sound intensity in W/cm^2 .
Show work.
- (1) 8. The sound of one Christmas caroler is about 60 dB.
Suppose we have 4 carolers, each singing at an intensity which produces a loudness level of 60 decibels.
What is the loudness level in decibels, of this quartet? _____ dB (round to 1 decimal place)
Hint 1: Use your equation.
Hint 2: The sound intensity is quadrupled.
- (1) 9. Attach a typed page which addresses the following items:
o What did you learn from this assignment that you did not know before?
o You have seen what a decibel is. How would you think a Bel would be defined?
Why is sound measured in decibels instead of Bels?