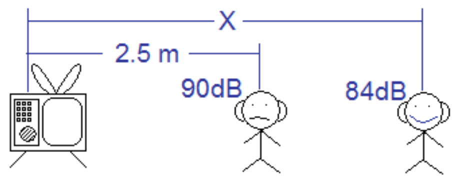
Physics I

Sound Intensity

Sound intensity $I=\frac{\text{power}}{\text{area}}$ or in decibels $\beta=10\log\left(\frac{I}{1\times10^{-12}\text{Wm}^{-2}}\right)$

Problem 1.- You are 2.5m away from the speakers of a TV set (a vintage one in the figure) and you hear the sound at a level of 90 dB. How far away do you need to be if you want the intensity to be 84dB?
You can assume the intensity is distributed over an area $2\pi R^2$.



Solution: To reduce the intensity 6dB we need to reduce I by a factor of 4. Doubling the distance will increase the area by a factor of 4 accomplishing this. So, the answer is x = 5m

Problem 1a.- You are 6 meters away from an un-muffled diesel engine and the noise level is 126 dB. How far do you need to be for the noise level to be 80 dB?
Take the area to be $2\pi R^2$

Solution: The difference in intensity is 46dB, which is equivalent to a factor of 40,000.
To reduce the intensity that much you must be 200 times further away or **1200m** away.

Problem 1b.- At a concert you are sitting 120 m from the speakers and feel the sound level at an intensity of 115 dB. How much is the intensity for a person 60m away from the speakers? Assume that the power spreads uniformly.

Solution: The person that is at 60m from the source will perceive a higher intensity. Notice that the area will be only ¼ of the one at 120m due to having half the radius. Hence, the intensity will be 4 times louder or 6dB higher.

Answer: **121 dB**

Problem 2.- The label on a speaker box claims that it delivers a power of 350 W. If this power were equally distributed in all directions, what would be the intensity of the sound in decibels at 25 m from the speaker?

Solution: The intensity in W/m^2 is

$$I=\frac{\text{Power}}{\text{Area}}=\frac{350\text{W}}{4\pi R^2}=\frac{350\text{W}}{4(3.1416)(25\text{m})^2}=0.0446\text{W/m}^2$$

And converting this intensity to decibels:

$$\beta = 10\times\log_{10}\left(\frac{I}{I_o}\right) = 10\times\log_{10}\left(\frac{0.0446\,W/m^2}{10^{-12}\,W/m^2}\right) = \mathbf{106.5\ dB}$$

Problem 2a.- A barking dog delivers 3.5×10^{-3} W of power, which you can assume to be uniformly distributed in all directions. What is the intensity in decibels at 5.8 m from the dog?

Solution: First the intensity in watts per square meter

$$I = \frac{Power}{Area} = \frac{3.5\times10^{-3}}{4\pi\times5.8^2} = 8.27\times10^{-6}$$

And now in decibels $\beta = 10\log\left(\frac{8.27\times10^{-6}}{1\times10^{-12}}\right) = \mathbf{69.2\ dB}$

Problem 3.- Calculate the power delivered by the speakers in a concert if the intensity reached β=115 dB at 20m. In your estimation, assume an area of distribution of half a sphere ($2\pi R^2$).

Solution: We convert the intensity in decibels to raw intensity using the definition:

$$115 = 10\log\left(\frac{I}{10^{-12}}\right) \rightarrow \log\left(\frac{I}{10^{-12}}\right) = 11.5 \rightarrow \frac{I}{10^{-12}} = 10^{11.5} \rightarrow I = 10^{-0.5} = 0.316\,W/m^2$$

And to get the power we multiply by the area:

$$Power = IA = 0.316\times\left(2\pi R^2\right) = 0.316\times\left(2\pi\times20^2\right) = \mathbf{794\ watts}$$

Problem 4.- A mosquito located two meters away produces a sound intensity of 85 dB. How much would the intensity be if there were 200 mosquitoes at the same distance?
You can assume that the sound is equally distributed in all directions.

Solution: Since 200 = 2×10×10 we need to add 3dB + 10dB + 10dB to account for the three factors, so the sound will have an intensity of **108 dB**

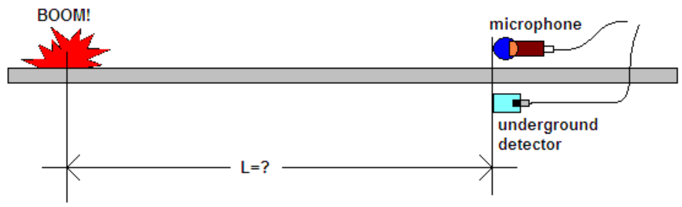
Problem 4a.- Two jet engines together produce a sound intensity of 116 dB at a certain distance. How much would the intensity be if you had just one jet engine at the same distance?

Solution: A drop in intensity by half is the same as -3 dB, so answer: **113dB**

Problem 4b.- A jet engine produces a sound intensity of 115 dB at a certain distance. How much would the intensity be if you had *four* jet engines at the same distance?

Solution: The intensity of one jet is: $I_1 = 10^{\beta/10} I_o$ and the intensity of four of them will be:
$I_4 = 4 \times 10^{\beta/10} I_o$,
So the new intensity in dB is $\beta_4 = 10\log(4\times 10^{\beta/10}) = \beta + 10\log(4) =$ **111 dB**

Problem 5.- An explosion on a paved street is detected by a ground detector and a microphone with a delay of 1.43 s. Calculate the distance from the explosion to the instruments. [Speed of sound in air = 343m/s   Speed of sound in concrete = 3,000 m/s]



Solution: The delay between the two instruments is the difference in time between the two signals, which gives us the equation:

$$\frac{L}{343m/s} - \frac{L}{3000m/s} = 1.73s \rightarrow L = \frac{1.73s}{\dfrac{1}{343m/s} - \dfrac{1}{3000m/s}} = \textbf{670 m}$$

Problem 6.- On the morning of August 27, 1883, the Krakatoa volcano's vents sunk below sea level, letting seawater flood into it and causing a massive explosion.
We will make a very rough estimate of the sound intensity in Los Angeles (distance to Krakatoa, R=1.2×10^7 m). Assume the power of the sound wave was 3.2×10^{13} W and consider that the wave was distributed over an area $4\pi R^2$, which is an exaggeration, but partially compensates for not considering attenuation.

Solution: Our estimation of the intensity gives:

$$I = \frac{Power}{Area} = \frac{Power}{4\pi R^2}$$

In decibels:

$$\beta = 10\times\log\left(\frac{I}{I_o}\right) = 10\times\log\left(\frac{Power}{I_o 4\pi R^2}\right)$$

With the values of the problem:

$$\beta = 10\times\log\left(\frac{3.2\times10^{13}W}{1\times10^{-12}W/m^2 4(3.1416)(1.2\times10^7 m)^2}\right) = \textbf{102.5 dB}$$