18) If The Intensity Level By 10 Identical Engines In A Garage Is 100 Db, What Is The Intensity Level

Understanding Sound Intensity and Decibel Levels: What Happens When Multiple Engines Run Simultaneously?

18) If The Intensity Level By 10 Identical Engines In A Garage Is 100 Db, What Is The Intensity Level is a typical question in acoustics that explores how sound levels combine when multiple sources are operating at the same time. This scenario is common in settings such as garages, factories, or workshops where several engines or machines may be running simultaneously. To accurately answer this question, it is essential to understand the fundamentals of sound intensity, decibel measurement, and how these quantities interact when multiple sources are involved.

Fundamentals of Sound Intensity and Decibels

What Is Sound Intensity?

Sound intensity refers to the power carried by sound waves per unit area, usually measured in watts per square meter (W/m^2). It represents the actual energy transmitted through a given area by the sound waves. The greater the intensity, the louder the sound perceived by human ears.

Decibel Scale Explained

The decibel (dB) is a logarithmic scale used to quantify sound levels. Because human hearing is sensitive over a wide range of intensities, the decibel scale compresses this range into a manageable form. The basic formula for sound intensity level in decibels is:

- Sound Intensity Level (dB) = $10 \times \log_{10}(I / I_0)$

where:

- I = intensity of the sound wave

- I_0 = reference intensity, typically 1×10^{-12} W/m²

Relationship Between Multiple Sources and Sound Levels

When multiple sound sources are involved, their intensities add together, but their decibel levels do not simply sum. Because the decibel scale is logarithmic, combining multiple sources requires converting decibel levels back to intensities, adding these intensities, and then converting back to decibels.

Calculating the Combined Intensity Level of Multiple Engines

Step 1: Understand the Given Data

In the scenario, 10 identical engines produce a combined sound level of 100 dB. This information allows us to find the individual intensity level of one engine.

Step 2: Find the Intensity of a Single Engine

Since the engines are identical, their intensities are equal. The total intensity (I_{total}) from 10 engines is the sum of their individual intensities (I_{single}):

- $I_{total} = 10 \times I_{single}$

Using the decibel formula:

$$100 \text{ dB} = 10 \times \log_{10}(I_{total} / I_0)$$

Rearranged to find I_{total}:

$$I_{total} = I_0 \times 10^{(100/10)} = I_0 \times 10^{10}$$

Similarly, for a single engine:

$$I_{single} = I_0 \times 10^{(L_{single}/10)}$$

Step 3: Find the Intensity Level of a Single Engine

Since $I_{total} = 10 \times I_{single}$, then:

$$I_{single} = I_{total} / 10 = I_0 \times 10^{10} / 10 = I_0 \times 10^9$$

Now, compute the decibel level of a single engine:

$$L_{single} = 10 \times \log_{10}(I_{single} / I_0) = 10 \times \log_{10}(10^9) = 10 \times 9 = 90 \text{ dB}$$

Determining the Total Sound Level When Multiple Engines Operate

Step 4: Adding Additional Engines

Now, suppose we want to find the combined decibel level when a different number of identical engines are running. The key principle is that adding sources increases the total intensity, which in turn increases the decibel level.

Step 5: General Formula for Multiple Sources

Given that each engine has an intensity level of $L_{single} = 90$ dB, the total intensity from N engines is:

$$I_{total} = N \times I_{single}$$

Expressed in decibels, the combined level L_{total} is:

$$L_{total} = 10 \times \log_{10}(I_{total} / I_0) = 10 \times \log_{10}(N \times I_{single} / I_0) = 10 \times \log_{10}(N \times 10^{(L_{single}/10)})$$

Using logarithm properties:

$$L_{total} = 10 \times [\log_{10}(N) + (L_{single}/10)] = 10 \times \log_{10}(N) + L_{single}$$

Applying the Formula to the Given Scenario

Step 6: Find the Total Level for 10 Engines

Given that:

- N = 10
- L_{single} = 90 dB

Calculate:

$$L_{total} = 10 \times \log_{10}(10) + 90 = 10 \times 1 + 90 = 100 \text{ dB}$$

This confirms the initial data that 10 engines produce 100 dB.

Step 7: Find the Total Level for a Different Number of Engines

Suppose we want to know the sound level when, say, 20 engines are running. Using the formula:

$$L_{total} = 10 \times \log_{10}(20) + 90$$

Calculate log10(20):

$$\log_{10}(20) \approx 1.3010$$

Therefore:

$$L_{total} \approx 10 \times 1.3010 + 90 = 13.01 + 90 = 103.01 \text{ dB}$$

Similarly, for 100 engines:

$$L_{total} = 10 \times \log_{10}(100) + 90 = 10 \times 2 + 90 = 110 \text{ dB}$$

Answer to the Original Question

What Is the Intensity Level When 10 Engines Are Running?

As established, when 10 identical engines operate simultaneously, the combined sound level is 100 dB. The individual engine's sound level is 90 dB because:

$$L_{single} = L_{total} - 10 \times \log_{10}(N) = 100 - 10 \times 1 = 90 \text{ dB}$$

What If the Number of Engines Changes?

If the question pertains to a different number of engines, we can adjust accordingly. For example, if more engines are added, the total decibel level increases logarithmically, following the formula:

$$L_{total} = 90 + 10 \times \log_{10}(\text{Number of engines})$$

Practical Implications of Sound Level Calculations

Understanding Noise Pollution

Knowing how multiple sources contribute to overall noise levels is vital in managing noise pollution. For example, in a garage or factory setting, understanding how increasing the number of engines affects total noise can

Frequently Asked Questions

If the intensity level by 10 identical engines in a garage is 100 dB, what is the intensity level produced by a single engine?

The intensity level of a single engine is approximately 90 dB.

How does adding more engines affect the overall intensity level in decibels?

Adding more identical engines increases the overall intensity level logarithmically, with each doubling of engines adding about 3 dB.

What is the formula to calculate the intensity level when multiple identical sources are involved?

The total intensity level in decibels is given by L_total = L_single + 10 log10(N), where N is the number of sources.

Given that 10 engines produce 100 dB, what is the intensity level contributed by one engine?

One engine contributes approximately 90 dB, since 10 engines at 100 dB is 10 log10(10) = 10, indicating each contributes roughly 90 dB.

If the number of engines increases to 20, what would be the new intensity level?

The new intensity level would be approximately 103 dB, since doubling the number of engines adds about 3 dB.

Why does the decibel level increase by 3 dB when the number of engines doubles?

Because decibels are logarithmic, doubling the number of identical sound sources adds approximately 3 dB to the total intensity level.

Additional Resources

If the intensity level by 10 identical engines in a garage is 100 dB, what is the intensity level?

Introduction

Sound is an integral part of our environment, influencing everything from communication to entertainment. However, understanding the nuances of sound intensity and how it combines when multiple sound sources are involved can be quite complex. One common question in acoustics involves calculating the overall sound level when multiple identical sources operate simultaneously. Specifically, if ten identical engines in a garage produce a combined sound level of 100 decibels (dB), what is the sound level produced by a single engine? This article explores this question in depth, providing a comprehensive analysis of

sound intensity levels, the principles of combining sound sources, and the mathematical foundations that allow us to decode such acoustic puzzles.

Understanding Sound Intensity and Decibel Levels

What is Sound Intensity?

Sound intensity refers to the power carried by sound waves per unit area, typically measured in watts per square meter (W/m^2). It quantifies how much energy passes through a given area in a given time, representing the physical strength of the sound. Unlike loudness, which is subjective, intensity is an objective physical measurement.

The Decibel Scale

The decibel (dB) is a logarithmic unit used to express ratios of physical quantities, particularly in acoustics. It is defined as:

$$ L = 10 \times \log_{10} \left(\frac{I}{I_0} \right) $$

where:
- $ L $ is the sound level in decibels,
- $ I $ is the intensity of the sound,
- $ I_0 $ is a reference intensity, usually the threshold of hearing $ (1 \times 10^{-12} \, \text{W/m}^2) $.

Because of its logarithmic nature, each increase of 10 dB corresponds to a tenfold increase in intensity.

Loudness Perception

While decibel levels provide an objective measure, human perception of loudness is nonlinear. For example, a sound that is 10 dB louder than another is perceived as roughly twice as loud, but the actual increase in intensity is tenfold.

The Principle of Combining Multiple Identical Sound Sources

Logarithmic Nature of Sound Levels

When multiple identical sound sources operate simultaneously, their combined effect on the sound level isn't a simple addition of their individual dB levels. Instead, because decibels are logarithmic, their intensities—rather than their dB levels—are summed.

Combining Identical Sources

If each source produces the same intensity $ I_s $, then the total intensity $ I_{total} $ when $ N $ sources are active is:

$$ I_{total} = N \times I_s $$

The total sound level L_{total} is then:

$$ L_{total} = 10 \times \log_{10} \left(\frac{I_{total}}{I_0} \right) $$

which simplifies to:

$$ L_{total} = 10 \times \log_{10} \left(N \times \frac{I_s}{I_0} \right) $$

$$ L_{total} = 10 \times \left(\log_{10} N + \log_{10} \left(\frac{I_s}{I_0} \right) \right) $$

$$ L_{total} = 10 \times \log_{10} N + L_s $$

where L_s is the decibel level of a single source.

Deciphering the Given Data

The Scenario

- Number of engines: 10
- Combined sound level: 100 dB
- Question: What is the sound level of a single engine?

Using the principles outlined above, the total level of 100 dB results from the combined intensities of all ten engines.

Mathematical Approach

Rearranging the equation:

$$ L_{total} = L_s + 10 \times \log_{10} N $$

Plugging in the known values:

$$ 100\, \text{dB} = L_s + 10 \times \log_{10} 10 $$

Since:

$$ \log_{10} 10 = 1 $$

then:

$$ 100 = L_s + 10 \times 1 $$
$$ 100 = L_s + 10 $$

Solving for L_s:

$$ L_s = 100 - 10 = 90\, \text{dB} $$

Therefore, the sound level of a single engine is 90 dB.

Implications and Contextual Analysis

Significance of the Result

The calculation reveals that each engine, when operating alone, produces a sound level of approximately 90 dB. When ten such engines operate simultaneously, their intensities combine to roughly double the perceived loudness, resulting in a 100 dB environment.

Real-World Applications

Understanding these principles is crucial in various fields:

- Workplace safety: Engineers and safety officers must assess cumulative noise exposure to prevent hearing loss.
- Environmental noise management: Urban planners and policymakers need to evaluate the impact of multiple sources like traffic, factories, or events.
- Acoustic design: Architects and sound engineers use these calculations to design spaces with acceptable noise levels.

Limitations and Considerations

While the calculation assumes perfect coherence and identical sources, real-world scenarios often involve:

- Different source intensities: Not all engines produce equal sound levels.
- Phase differences: Sound waves may not be perfectly in phase, affecting how they combine.
- Environmental factors: Reflections, absorption, and background noise influence perceived levels.

Broader Perspective on Sound Level Calculations

Summation of Non-Identical Sources

If sources are not identical, the total sound level involves summing their individual intensities, considering their respective levels:

$$ I_{total} = \sum_{i=1}^{N} I_i $$

which translates into a more complex calculation, often requiring detailed data about each source.

Safety Guidelines

The World Health Organization (WHO) and occupational safety agencies recommend

maximum noise exposure levels:

- 85 dB for 8 hours: Prolonged exposure above this can cause hearing damage.
- 10 dB increase doubles perceived loudness but should be carefully managed to prevent health risks.

In the scenario with 100 dB from ten engines, exposure might be hazardous without proper hearing protection.

Conclusion

The analysis of how multiple identical sound sources combine to produce a higher overall sound level underscores the importance of understanding acoustic principles. In the case of ten engines producing 100 dB collectively, each engine must produce approximately 90 dB when operating alone. This finding not only elucidates the mathematical relationship between individual and combined sound levels but also highlights practical considerations in noise management and safety.

Recognizing the logarithmic nature of sound measurement enables engineers, safety professionals, and policymakers to make informed decisions, ensuring environments are both productive and safe. As we continue to develop technologies and urban landscapes, mastering these foundational concepts remains essential for mitigating noise pollution and protecting human health.

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