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A1_13 Intensity of Sound

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Abstract

This paper investigates what power a musical instrument, including the human voice, would need to sustain to shatter a crystal wine glass at 1 m away due to resonance. The required power is determined to be 0.013 W.

Introduction

The natural frequency of a system is the number of times the system naturally oscillates each second, given no external interference. If a driving frequency excites a system at its natural frequency, a large vibration amplitude builds up called resonance. Undesirable resonance can cause problems, such as causing bridges to collapse [1].

Another example of resonance is a crystal glass shattering due to a musical note being sustained at its natural frequency. This paper investigates at what power a musical note must be sustained from 1 m away to shatter a crystal wine glass.

Investigation

An empty crystal wine glass has a natural frequency of approximately 677 Hz [2]. This frequency can be achieved by many musical instruments, including the human voice, which has a range of approximately 500 Hz to 2 kHz [4].

The stem of a wine glass reduces the amount of damping that could be caused by the surface it sits on, compared to a pint glass for example. The intensity level required to shatter a glass is at least 90 dB [5].

Sound intensity, *I*, is defined as [6]:

$$I = \frac{P}{4\pi r^2}, \qquad (1)$$

where *P* is sound power and *r* is the distance from the sound source. So, in order to determine the sound power needed to shatter the glass, the required intensity level at the glass must be determined. A logarithmic scale is best used to describe the intensity level, β, of a sound wave, which is measured in decibels (dB) [7]:

$$\beta = 10 \log_{10}\left[\frac{I}{I_0}\right], \qquad (2)$$

where $I_0 = 10^{-12}$ Wm^{-2} [8].

Assuming β must be at least 90 dB, the minimum sound power required at 1 m from the glass to shatter it can be determined by rearranging equations (1) and (2):

$$P = 4\pi r^2 I = 4\pi r^2 I_0 10^{\left(\frac{\beta}{10}\right)} = 0.013 \text{ W}.$$

Conclusion

The minimum power of a sustained corresponding musical note required to shatter the glass from a distance of 1 m away has been found to be 0.013 W. This is obtained under the assumption that the energy of sound waves is conserved. A human voice shouting can produce an acoustic power of 1 mW [9], so an amplifier would probably be needed to produce the necessary power.

References

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