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P4 7 I'd Like to Cast Thunderwave

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Abstract

We investigate the amount of sound energy required for a "Thunderwave" spell to move a Kraken as is theoretically possible in Dungeons and Dragons. We find that the huge sound involved would be the similar to a rocket between 165 dB and 175 dB and would rupture the casters' eardrums.

Introduction

Dungeons and Dragons ("D&D") offers many spells, one is called "Thunderwave". This creates a loud sound which pushes creatures away. The spell description sets no size limit for creatures moved [1]. We consider what would happen if the largest creatures in the game (gargantuan) were in the range of the spell when it was cast.

We use the iconic Kraken (large octopus) for this, in D&D these require at least a 20 ft cube of space [2]. We assume our Kraken is land-based, and whilst this does not align with Kraken lore, our Kraken is assumed to be "homebrewed" (self-created) and can live successfully on land.

Building a Kraken

A common octopus' tentacles are 0.76 m - 1 m, its mantle length 0.15 m - 0.25 m, and their mass 3 kg - 10 kg [3]. Henceforth, we use these ranges to find upper and lower limits for our results. We model its mantle as a prolate spheroid with a polar diameter, p, given by the mantle length. Its equatorial diameter, a, is unknown and is approximated as $\frac{3}{4}$ of its polar diameter. This was chosen given the absence of data. We needed an arbitrary approximation for calculations and this appeared sensible.

$$V_{mantle} = \frac{4}{3}\pi \left(\frac{a}{2}\right)^2 \frac{p}{2} \tag{1}$$

From Equation 1, the volume of the mantle, V_{mantle}, is 9.9×10^{-4} m^3 - 4.6×10^{-3} m^3. Approximating the base area of each tentacle as $\frac{1}{9}$ of the area of the equatorial plane (to account for the beak), we can calculate the volume associated with all of the octopus' 8 tentacles, $V_{tentacle}$ by approximating them as cones as in Equation 2,

$$V_{tentacle} = \frac{8}{3}\pi r^2 l \tag{2}$$

where l is tentacle length, and r is given by $\frac{1}{8}p$, which is derived from a total base area of $\pi\left(\frac{a}{2}\right)^2$. The volume is 2.2×10^{-3} m^3 - 8.2×10^{-3} m^3.

Hence, total volume is between 3.2×10^{-3} m^3 and 1.3×10^{-2} m^3. Using mass, we calculate octopus densities of 230 kgm^{-3} and 3100 kgm^{-3}.

To assess the spell's impact on a Kraken, we need its dimensions. We scale the octopus up to extrapolate mass. By D&D rules, the Kraken entirely inhabits a 20 ft cube (this is a lower limit). Octopuses are known for being able to squeeze into tight spaces, and we imagine that the Kraken is able to contort into a 20 ft cube

to obtain an approximation of its mass between 5.2×10^4kg and 7.0×10^5 kg.

Casting a Spell on a Kraken

"Thunderwave" is assumed to push the Kraken with force equivalent to sliding it across concrete. Treating its skin as rubber-like, the coefficient for kinetic friction, μ_k, is 0.6 [4].

"Thunderwave" pushes a creature by 10 ft [1]. The energy required to move the Kraken is found by calculating the force, F, as in Equation 3,

$$F = \mu_k m g \tag{3}$$

Where m is mass and g is gravitational acceleration. The force is 3.1×10^5 N - 4.1×10^6 N. Therefore, work done is 9.4×10^5 J - 1.2×10^7 J.

Regretting Casting a Spell on a Kraken

This spell relies on sound energy, we assume it all converts to kinetic energy against the Kraken, hence subsequent calculations are underestimates.

The relationship between sound pressure level (SPL) and sound energy (Figure 1) is found by converting SPL, to a sound pressure, P, as in Equation 4,

$$P = p_0 \times 10^{\frac{SPL}{20}} \tag{4}$$

where p_0 is a reference pressure (20 μPa) [5]. Before converting to intensity, I, using Equation 5,

$$I = P^2(\rho v_{sound})^{-1} \tag{5}$$

where ρ is air density (1.21 kgm^{-3}), and v_{sound} is speed of sound (344 ms^{-1}). Sound energy, E_s, is given by Equation 6,

$$E_s = IAT \tag{6}$$

where A is area of the Kraken cube, and T is duration of the spell (2 seconds).

Conclusion

Our analysis shows the energy involved in a "Thunderwave" spell varies with SPL. At a minimum, 165 dB is required to move the Kraken, which is above the threshold for eardrum rupture [6]. Also, it is a weak spell, doing 40 damage at a maximum level cast [1]. Compared to the 472 damage required to kill a Kraken [7], it would take 12 attempts. You both would have lost your hearing long before then.

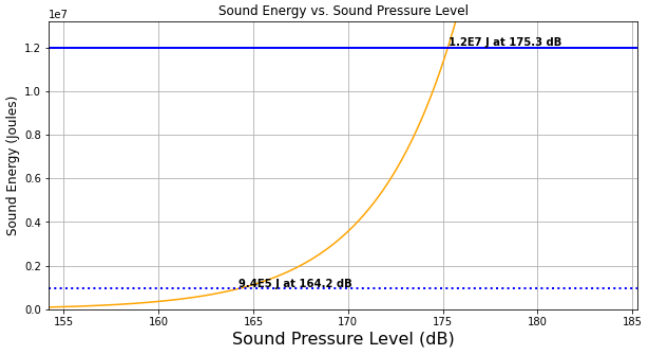

Figure 1: A plot showing how the energy involved in the spell corresponds to SPL. The spell would cause a sound between ≈165 dB and ≈175 dB.

In conclusion, while "Thunderwave" could affect a Kraken, practical limitations suggest there are more effective strategies for combat.

References

[1] `https://www.dndbeyond.com/spells/thunderwave` [Accessed 3 November 2023]

[2] `https://www.dndbeyond.com/sources/basic-rules/monsters` [Accessed 3 November 2023]

[3] `https://www.dimensions.com/element/common-octopus-octopus-vulgaris` [Accessed 3 November 2023]

[4] `https://mechguru.com/machine-design/typical-coefficient-of-friction-values\-for-common-materials/` [Accessed 3 November 2023]

[5] `https://www.acoustic-glossary.co.uk/sound-pressure.html` [Accessed 3 November 2023]

[6] `https://soundproofingguide.com/decibels-level-comparison-chart/` [Accessed 3 November 2023]

[7] `https://www.dndbeyond.com/monsters/16940-kraken` [Accessed 3 November 2023]