A4_2 Horn to Kill

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Abstract

In this paper, the level of sound from a car horn required to halt an incoming car travelling at a typical speed of 60 mph in an emergency was calculated. This required level was found to be approximately 240 dB, a sound 10^{14} times louder than a regular 100 dB car horn. This level of noise would cause a large amount damage to both vehicles involved.

Introduction

Car horns as well as those on other automobiles are typically used to alert other drivers on the road of your existence and of potential dangers. Unfortunately, this is not always sufficient in preventing an accident and potentially saving your life due to the other driver involved. Although since sound waves are travelling pressure waves of air, a powerful enough sound could provide a force great enough to decelerate an incoming car quickly to avoid disaster.

Equations

To begin, Newton's second law can be employed to determine the force, F, required to halt a car travelling towards the horn at a velocity v_{car} in time t as in Eq.(1)

$$F = \frac{mv_{car}}{t} \tag{1}$$

Power radiated by a sound wave against a body can be determined with Eq.(2) where I is the intensity of the wave and A is the area of the body that the power is radiated to. Power can also be determined by Eq.(3) with Force applied, F, while moving at a velocity, v.

$$P = IA \tag{2}$$

$$P = Fv \tag{3}$$

Eq.(2) and Eq.(3) can be equated and rearranged to give Eq.(4), where for the question at hand, $v = v_c + v_{car}$, where $v_c = 343$ ms^{-1} is the speed of sound in air, as the sound and the car are moving towards each other within the context of this question, such that v gives the speed of the sound relatively to the incoming car..

$$I = \frac{Fv}{A} \tag{4}$$

Since intensity, including in terms of sound level, follows an inverse-square law, decreasing with the distance from the source of the sound, the intensity of the sound produced by the horn can be found from rearranging Eq.(5), r refers to distance from the sound's generator, car refers to the car travelling towards the horn and $horn$ refers to where the sound exits the horn after being generated.

$$\frac{I_{horn}}{I_{car}} = \frac{r_{car}^2}{r_{horn}^2} \tag{5}$$

Noise level in decibels, S, is given by Eq.(6), where I is the intensity of the sound wave in

question, and I_0 is the reference intensity, typically quoted as the threshold intensity of human hearing, $I_0 = 1 \times 10^{-12}$ Wm^{-2} [1].

$$S = 10 \log \left(\frac{I}{I_0} \right) \qquad (6)$$

Results

From Eq.(1), taking the average mass of a car to be 1500 kg [2] and, for the sake of this thought experiment, choosing that we want to bring a car moving at 60 mph (or approx. 26.82 ms^{-1}) to rest within 2 seconds as a last second emergency stop, we find that force required for this deceleration is approximately $F = 20100$ N.

For the area of the car being directly impacted by the sound waves coming from the horn, we can take approximate dimensions for the height and width of an average car, 1.53 m and 1.82 m [3], resulting in $A = 2.78$m^2. With this value, our value $v = 370$ ms^{-1} ($v = v_c + v_{car}$ as previously stated), and our value for the acoustic force required, we can use Eq.(4) to find the intensity required at the car to be $I = 2.67$ MWm^{-2}.

A typical compact car horn is relatively small, with the sound waves exiting the horn from as small as 5 cm from the actual source of the sound. As such we can determine the intensity needed to be produced for the sound waves exiting the horn when the car is at a distance of 30 m away when the horn begins, using Eq.(5), which evaluates as $I_{horn} = 962$ GWm^{-2}. Finally, using this value in Eq.(6), results in a noise level of $S = 240$ dB.

Discussion

A noise level of 240 dB does not sound too bad considering an average car horn can be anywhere in a range from 90-110 dB depending on your model of car and your region's vehicle safety laws. However, an increase from 100 dB to 240 dB, due to the decibel's logarithmic calculation, has the effect of increasing the intensity and energy of the sound by a factor of 10^{14} which is a tremendous amount of energy and sound. To provide even more of a frame of reference for the magnitude of this volume, the noise level

required to burst a human's eardrums sits at around 160 dB, while the loudest sound producible on Earth is around 190 dB. [4] Because of these facts, a horn of this power would clearly be impossible to create on Earth, and in any kind of practical setting, a force this great produced from a horn would surely damage the target car beyond repair, likely kill any occupants, and is sure to do the same to the vehicle and passengers operating said horn to avoid a potential disaster.

The distance of the target car from the horn at the start of deceleration does also have some amount of impact on the validity of the question asked, since if the deceleration began when r_{car} is below a certain limit, the car would continue to reach the horn before coming to a halt, defeating the point of the question. Using the equations of motion it can be determined simply that the minimum distance required to stop in the time previously stated would be approximately 27 m. This is without taking into account the increased force as the car gets closer during deceleration, meaning that the selected value of 30 m is well within a lower bound of possible choices here.

Conclusion

Using sound to stop a directly incoming car travelling the national speed limit, while is theoretically doable by the known laws of physics, is not practically doable on Earth with our current levels of technology. Even if this was within the realms of possibility, with our limitations, you would likely end up doing more harm than if you did nothing at all due to the forces applied radially around the horn in question.

References

[1] https://www.acoustic-glossary.co.uk/sound-intensity.htm [Accessed 05/10/2022]

[2] https://hypertextbook.com/facts/2000/YanaZorina.shtml [Accessed 05/10/2022]

[3] https://www.nimblefins.co.uk/cheap-car-insurance/average-car-dimensions [Accessed 05/10/2022]

[4] https://boomspeaker.com/noise-level-chart-db-level-chart/ [Accessed 05/10/2022]