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P4_8 Doppler Ambulance

O.W. Morris, L.J. Banks, A.J. Laird, L.S. Morris

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In this paper, we investigate the scenario of an ambulance moving towards and away from an observer at rest. We calculated the maximum velocity, of both the ambulance travelling towards and away, required for the siren to be inaudible to humans. It was found that an ambulance travelling towards and away from an observer, velocities of 331 ms^{-1} and 16.0 kms^{-1} respectively would be required.

Introduction

An ambulance's siren toggles between two different frequencies that are usually set to be 700 Hz and 950 Hz [1]. When an ambulance travels at a high velocity, the frequency heard by an observer at rest significantly changes due to the Doppler effect. If the velocity increases above a certain value, the sound heard can be of a frequency too high or too low for humans to hear depending on the direction of travel. This effect occurs as the vehicle is in motion. The effective wavelength of the sound produced by the siren changes, as a result the heard frequency changes.

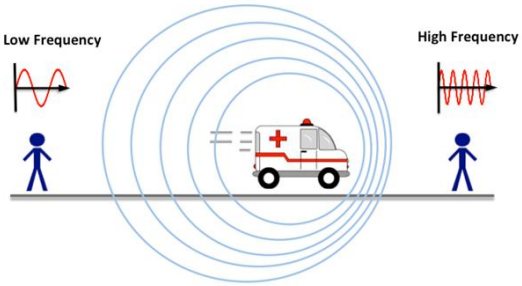

Figure 1: Scenario diagram where low frequency occurs when ambulance is travelling away from observer and high frequency occurs when ambulance is travelling away towards the observer [3].

Method and Equations

To calculate the desired velocities, the Doppler effect was used twice. For an object moving towards an observer at rest, Eq. (1) was used and when travelling away, Eq. (2) was used [2].

$$F' = \frac{V}{V - V_{towards}} F_s \tag{1}$$

$$F' = \frac{V}{V + V_{away}} F_s \tag{2}$$

The Doppler equations calculate the frequency of heard sound waves (F'), with the use of:

V, the velocity of sound (343 ms^{-1}) [4].

$V_{towards}$ and V_{away}, the velocity of the ambulance towards and away from the observer respectively.

F_s, frequency emitted by the ambulance's siren (700 Hz and 950 Hz)[1].

These equations allowed for a visual comparison of the relationship between heard frequency and velocity. When an ambulance is modelled as moving towards a facing observer, the lower

emitted frequency (700 Hz) requires a higher velocity compared to that of the higher emitted frequency in order to reach the upper bound of human hearing, 20,000 Hz [5]. When an ambulance is modelled as moving away from an observer, the upper emitted frequency (950 Hz) requires a higher velocity compared to that of the lower emitted frequency to reach the lower bound of human hearing, 20.0 Hz [5].

Results

To discover the bound that required a higher velocity for each scenario, we displayed general results for Eq. (1) and Eq. (2) as plots. On Fig. 2 and Fig. 3, both source frequencies are displayed as different colours.

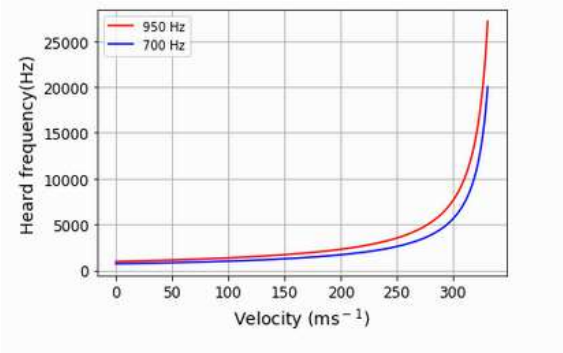

Figure 2: Using Eq. (1), a plot of the velocity against the heard frequency when the ambulance is travelling towards a stationary observer.

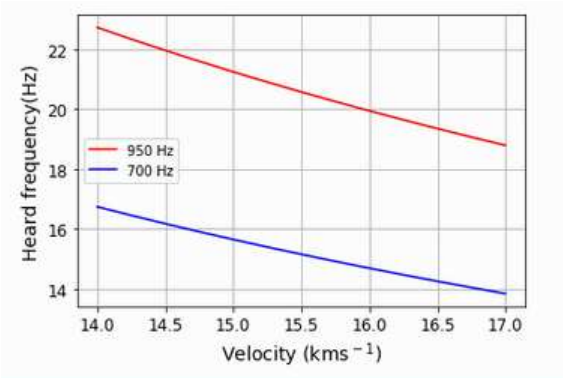

Figure 3: With the use of Eq. (2), relevant section of a plot of velocity vs heard frequency when the ambulance is travelling away from a stationary observer.

We could then substitute the correct frequency into each equation. With the aid of Figure 2 and Eq. (1), it was calculated that when the ambulance was modelled to be travelling towards an observer, a velocity of 331 ms^{-1} would be required to produce a heard frequency of 20,000 Hz. Next, with the aid of Figure 3 and Eq. (2), it was calculated that when the ambulance was modelled to be travelling away from an observer, a velocity of 16.0 kms^{-1} would be required to produce a heard frequency of 20.0 Hz. If the velocities increase, the heard frequency would continue to increase or decrease past the hearing range. However, if the velocities decrease, at least one of the sirens could become audible by humans. A further decrease in velocities would result in both siren pitches becoming audible.

Conclusion

The high velocities required for the siren to be inaudible by humans is not achievable by an ambulance on the Earth. However, another vehicle such as a jet could achieve the velocity required for the same produced sound to become inaudible if travelling towards an observer at rest. This cannot be stated for any vehicle on Earth said to be moving away from an observer; a spacecraft would be the only vehicle capable of the required velocity. To further the investigation, the experiment could be repeated with a observer that isn't stationary.

References

[1] Detection of Ambulance and Fire Truck Siren Sounds Using Neural Networks, T. vanthuan, Y. yu-cheng , T. wei-ho

[2] `https://bit.ly/32HA32d` [Accessed 20 November 2021]

[3] `https://bit.ly/3o7A1ca` [Accessed 20 November 2021]

[4] `https://bit.ly/3ya4lGI` [Accessed 20 November 2021]

[5] `https://bit.ly/3ov0fph` [Accessed 20 November 2021]