Doppler Effect

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Abstrct

This is an eassay focused on Doppler Effect and its applications which is developed by some formular derivation and explaination.

Keywords

Doppler Effect *frequency* *Relativistic Doppler Effect*

1.Introduction

The Doppler effect is a calssical phenomenon in physics that the change in frequency or wavelength of a wave is related to an obersver who is moving relative to the cave source.
This phenomenon is discovered by the Austrain physicist Christian Doppler in 1842,so the principle is named after him.

2.Approach to determine the detected frequency because of Doppler Effect

2.1.principles and formulus

in classical physics(low speed,macroscopic),where the velocity of source and the receiver relative to the medium are lower than the velocity of waves in the medium,relationship between observed frequency (f) and emitted frequency (f_0) can be given by:

$$f = \left(\frac{c \pm v_r}{c \pm v_s}\right) f_0 \dots\dots\dots\dots\dots\dots\dots\dots\dots [A]$$

symbol meaning explaination:

- c is the velocity of wave in the medium
- v_r is the velocity of the receiver relative to the medium;we use(+) if the receiver is moving to the source,else we use(-)in original fomular
- v_s is the velocity of the source relative to the medium;similarly,we use(+) if the source is moving away from the receiver,else we use(-) in original fomular

2.2. an example in calculating the detected frequency

A train is moving linearly and uniformly at the speed of 25m/s and its whisle frequency is 500Hz.Suppose the speed of sound in the air is 340m/s.A person standing beside the rail when the train passes him,we can calculate the real frequency this child hears in the way below:

$$f=\left(\frac{c \pm v_r}{c \pm v_s}\right) f_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [A]$$

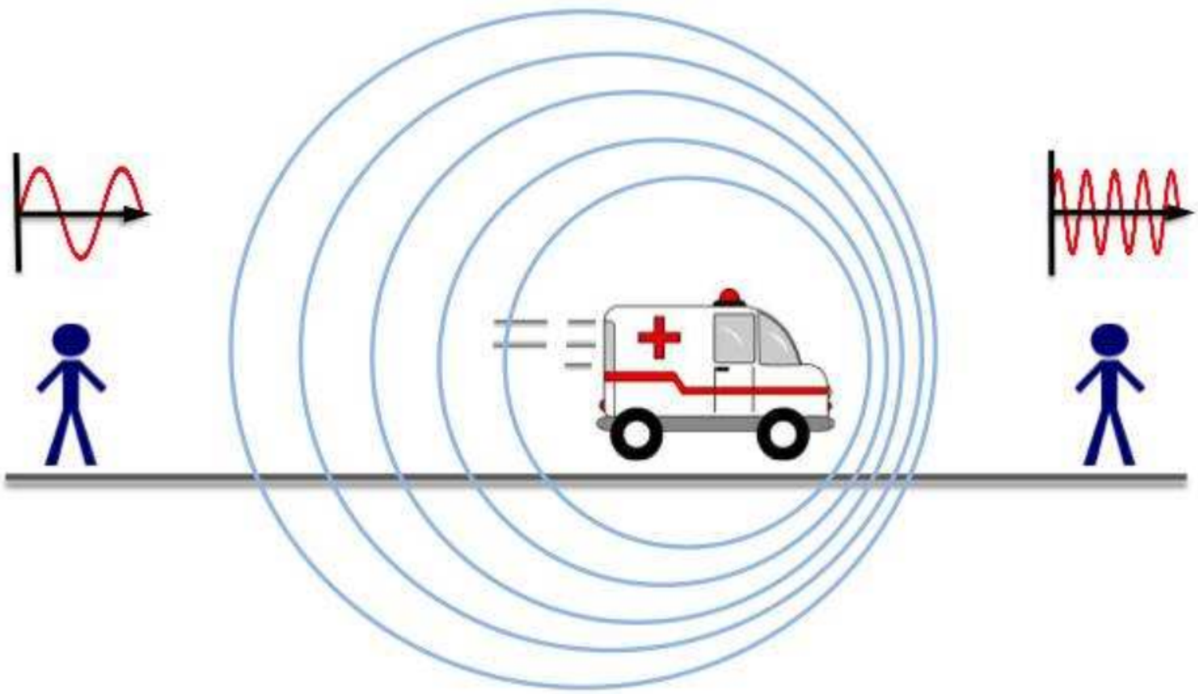
$$f=\left(\frac{340m/s+0m/s}{340m/s+25m/s}\right) * 50Hz = 40HZ$$

there are many applications according to basic calculation of Doppler Effect.Details about further applications are in the next part.

3.Doppler Effect for light

3.1.transition from sound to light

As discussed above on sound, if a source of sound and a listener are moving farther apart, the listener encounters fewer cycles of a wave in each second, and therefore lower frequency, than if their separation remains constant. For the same reason, the listener detects a higher frequency if the source and listener are getting closer.



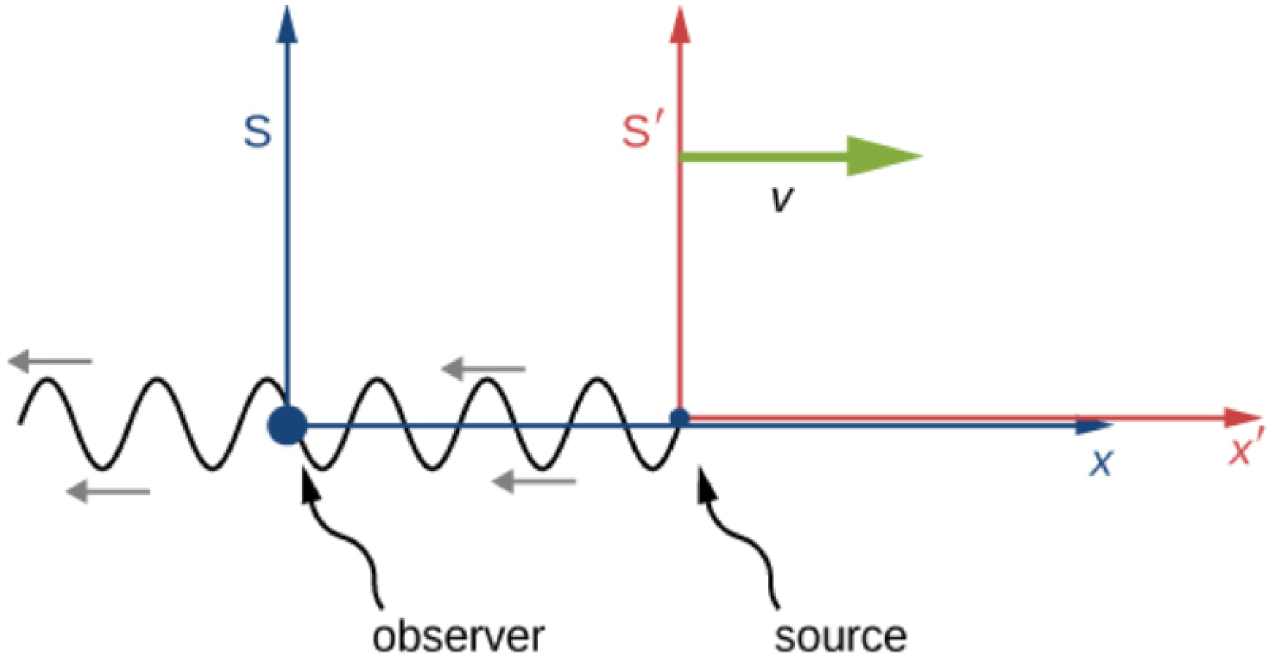
The resulting Doppler shift in detected frequency occurs for any form of wave. For sound waves, however, the equations for the Doppler shift differ markedly depending on whether it is the source, the observer, or the air, which is moving. **Light requires no medium, and the Doppler shift for light traveling in vacuum depends only on the relative speed of the observer and source.**

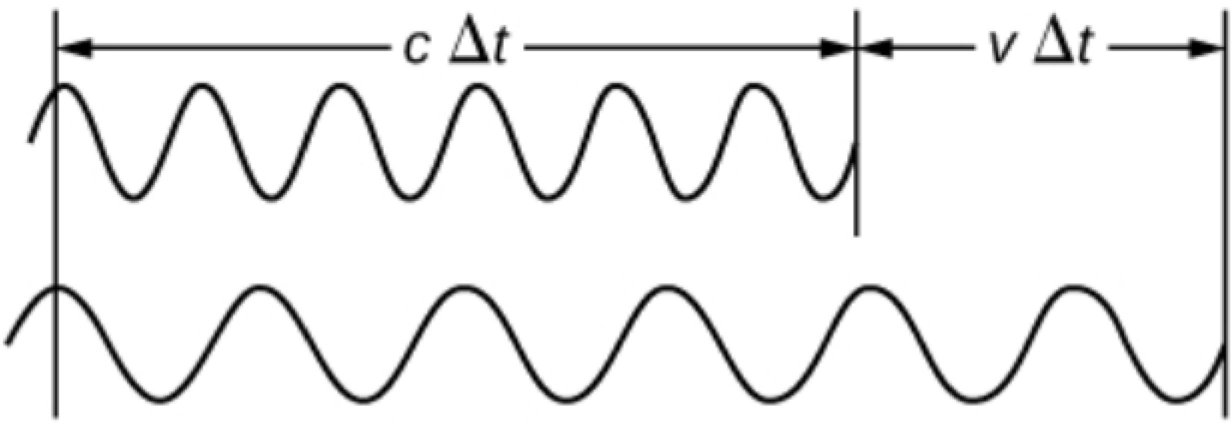
3.2.The Relativistic Doppler Effect

Suppose an observer in S sees light from a source in S'S′ moving away at velocity v (Figure). The wavelength of the light could be measured within S' — for example, by using a mirror to set up standing waves and measuring the distance between nodes. These distances are proper lengths with S' as their rest frame, and change by a factor:

$$\sqrt{1-\left(\frac{v^2}{c^2}\right)}$$

when measured in the observer’s frame S, where the ruler measuring the wavelength in S' is seen as moving.





If the source were stationary in S, the observer would see a length cΔt of the wave pattern in time Δt. But because of the motion of S' relative to S, considered solely within S, the observer sees the wave pattern, and therefore the wavelength, stretched out by a factor of

$$\left(\frac{c*\Delta t+v*\Delta t}{c*\Delta t}\right)=1+\left(\frac{v}{c}\right)$$

therefore,the overall increase from both effects gives: $$ \lambda_{observe}=\lambda_{source}*(1+{\left(\frac{v}{c} \right) }) *{\left(\frac{1}{ \sqrt{1-\left(\frac{v^2}{c^2} \right) }} \right) } =\lambda*{source}\sqrt{\left(\frac{1+\left(\frac{v}{c} \right)}{1-\left(\frac{v}{c} \right)} \right) }$$ then is the eventual relationship beween source wavelength and the wavelength we observe.This way we consider two effect(relativistic scaling effect and doppler effect) together,we call it relaticistic doppler effect

4.Applications about Doppler Effect

4.1.Frequency Mixer Based on Doppler Effect

scientists have proposed and demonstrated a novel mixer that requires no local oscillator (LO), but mixes the radio frequency (RF) with its Doppler shifted frequencies on a nonlinear reconfigurable composite right/left-handed transmission line, on which a moving reflective surface is controlled by an external digital circuit. An incident RF encounters a frequency shift when reflected from this moving surface and a difference frequency between the incident frequency and Doppler shifted frequency is generated on this nonlinear transmission line. This kind of mixer has the advantage in high frequency and cognitive radio applications since an LO is not required, meanwhile the intermediate frequency is also tunable electronically.

4.2 Red Shifts and Blue Shifts

The observed wavelength λobs of electromagnetic radiation is longer (called a “red shift”) than that emitted by the source when the source moves away from the observer. Similarly, the wavelength is shorter (called a “blue shift”) when the source moves toward the observer. The amount of change is determined by:

$$\lambda_{observe} = \lambda_{source} * \sqrt{\left(\frac{1+\left(\frac{v}{c}\right)}{1-\left(\frac{v}{c}\right)}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [B]$$

then：

$$f_{source} = f_{observer} * \sqrt{\left(\frac{1-\left(\frac{v}{c}\right)}{1+\left(\frac{v}{c}\right)}\right)}$$

through the transmition above we get the relationship between source frequency and obsercer frequency,we can clearly find [B] is differnt from [A].
through red shifts and blue shifts scientist find the universe is expanding.

5. Conclusion

I have researched on doppler effect from basic principle to some applications.This eassy mainly foucus on The Relativistic Doppler Effect and its application.its deduction Red Shifts and Blue Shifts has very broad applications in space area and we humanbeings are still searching.

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