# Doppler effect of a vehicle

FizziQ activity · High school · 35 min

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The frequency shift of a passing vehicle is analyzed with FizziQ's smartphone spectrum analyzer; students apply the Doppler formula to calculate its speed.

## Learning objectives

- Analyze the sound spectrum of a moving vehicle before and after it passes the observer
- Measure the apparent frequency shift caused by the Doppler effect
- Apply the Doppler equation to calculate the speed of the vehicle from the frequency shift
- Understand the physical mechanism behind the compression and stretching of sound waves
- Connect the Doppler effect to real-world applications in medicine, astronomy, and radar technology

## Instruments and sensors

Sound spectrum analyzer (FFT) · Microphone

## Materials

- Smartphone with the FizziQ application
- "Doppler Effect" recording from the FizziQ sound library, or a personal recording of a moving vehicle
- FizziQ experiment notebook (to log measured frequencies and results)
- Note: the protocol remains adaptable to any comparable spectral/audio analysis tool.

## Protocol

1. Open FizziQ and navigate to the Sound Library. Load the 'Doppler Effect' recording, which contains the sound of a vehicle passing the microphone.
2. Listen to the recording first. Notice the distinct change in pitch as the vehicle approaches and then recedes.
3. Open the Spectrum Analyzer (FFT) tool in FizziQ. Play the recording and pause during the approach phase (before the vehicle passes).
4. Identify the dominant frequency peak in the spectrum during the approach. Record this value as f_approach.
5. Resume playback and pause during the recession phase (after the vehicle has passed). Identify and record the dominant frequency as f_recede.
6. Calculate the frequency shift: $\Delta f$ = f_approach - f_recede.
7. Calculate the percentage shift: $\Delta f / f_0 \times 100$, where $f_0$ = (f_approach + f_recede) / 2 is the estimated emitted frequency.
8. Apply the Doppler formula to calculate the vehicle speed: v = c × (f_approach - f_recede) / (f_approach + f_recede), where c = 343 m/s is the speed of sound.
9. Convert the calculated speed to km/h by multiplying by 3.6.
10. Repeat the frequency measurement at several points during the approach and recession phases to verify that the frequency remains approximately constant during each phase.
11. If available, record your own Doppler effect audio by standing safely near a road and capturing the sound of a passing vehicle. Analyze it using the same method.
12. Discuss the assumptions made (straight-line motion, constant speed, observer perpendicular to the trajectory at the moment of passage) and how violations would affect the results.

## Expected results

For a typical vehicle traveling at 50 km/h (13.9 m/s), the frequency shift between approach and recession phases should be approximately 8% (4% higher during approach, 4% lower during recession). For example, if the engine's dominant tone is around 200 Hz, the approach frequency would be about 208 Hz and the recession frequency about 192 Hz. The calculated speed should be within 10-20% of the actual vehicle speed, with discrepancies arising from the fact that the vehicle may not be moving in a straight line directly toward and away from the microphone, the speed may not be perfectly constant, and the dominant frequency may be difficult to identify precisely in a complex engine sound spectrum. Students should observe that the frequency transition occurs rapidly at the moment of closest approach.

## Questions

- Why does the Doppler effect produce a higher pitch for an approaching source and a lower pitch for a receding one?
- What would happen to the perceived frequency if the observer were moving toward a stationary source?
- How is the Doppler effect used in medical ultrasound to measure blood flow velocity?
- What is the cosmological redshift, and how is it related to the Doppler effect?
- Why does the frequency change happen most rapidly at the moment of closest approach?
- What would the Doppler effect sound like if the vehicle were traveling at half the speed of sound?

## Going further

- Record the Doppler effect from different types of vehicles (car, motorcycle, truck) and compare the frequency shifts
- Investigate how the angle between the vehicle's trajectory and the observer affects the perceived frequency change
- Use two smartphones: one in a moving vehicle emitting a pure tone, and one stationary recording the Doppler-shifted sound
- Compare the Doppler shift for sounds of different frequencies emitted by the same moving source
- Calculate the speed of an emergency vehicle from its siren recording and compare with the posted speed limit