Fast and Curious

Pere Compte · Immacolata Ercolino · Philippe Jeanjacquot
Dionysis Konstantinou · Emmanuel Thibault

1 | Summary

The pupils measure the speed of an object using the Doppler effect of the sound. In this activity they use the audio (or video) file of the sound of a car.

- **Keywords:** Doppler effect, vehicle, speed, smartphones, sound
- **Disciplines:** physics, maths
- **Age level of students:** 17-18 years
- **Android apps:** Sound spectrum analyzer (SSA)
- **iOS apps:** iAnalyzer lite
- **Further functions needed:** camera for recording a video file, voice memo or sound recorder to record an audio file, signal generator for the extra activity

2 | Conceptual introduction

The objective is to measure the speed of a vehicle by recording the sound emitted by the vehicle when it passes a microphone (e.g. that of a smartphone). Measurements are made using smartphone spectrum analysis applications.

Required skills:

- Setting up an experiment to measure speed by using the Doppler effect.
- Using the expression describing the relative changes in frequency at low speeds.
- Using spectral data and image processing software to illustrate the applications of the Doppler effect as a method of investigation in astrophysics

Implied knowledge:

- The Doppler effect: The change of the observed frequency as the source moves towards and away from the observer.

3 | What the students do

This activity is divided into three parts:

- **As homework:** The students record the sound of a car or another vehicle by using their smartphones. (3.1.)
- **In class:** They explain what the Doppler effect is. (3.2)
- **Using their smartphones:** They measure and analyse the sound and determine the velocity of the car. (3.3)

3 | 1 Record the sound of a vehicle

In the first phase, the vehicle has to move towards the microphone; in the second phase it has to move away from it. It is better if the vehicle sounds its horn during the measurement. While the sound is being recorded, the vehicle is travelling in a straight line at a constant velocity (value: v).

For the recording, use either (i) the camera application for a video or (ii) the voice memo or sound recorder application for recording only the sound.

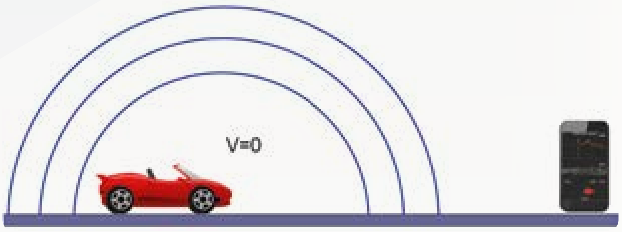
During the recording, the best method is to stand still and just turn the smartphone in the direction of the car. Be careful to record the car in a quiet place, without other noises.

3 | 2 What is the Doppler effect?

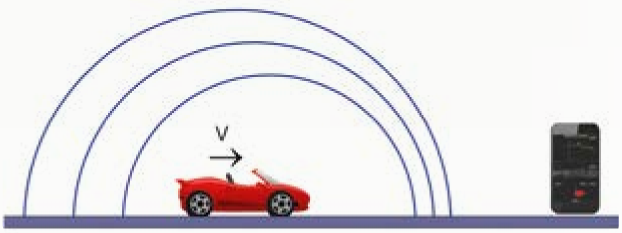
Listen to the recording and explain what characteristic of the sound is altered. In your explanation, make sure you distinguish between the two phases of the recording. The alteration is a result of the Doppler effect.

If the vehicle sounds its horn, the sound spectrum has peaks of frequency. Choose one peak with a very clear shift.

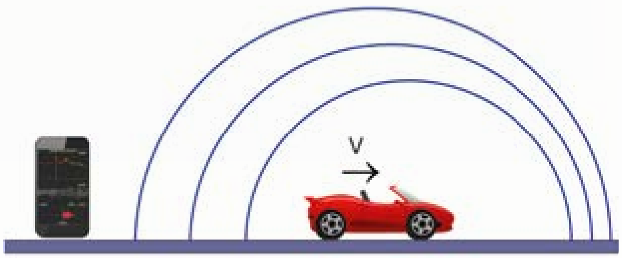
If the vehicle is at a standstill the frequency will be $f_{(0)}$.



If the vehicle is approaching the microphone, the pitch of the sound will be higher; the frequency increases to $f_{(1)}$.



If the vehicle is moving away from the microphone, the pitch of the sound will be lower; the frequency decreases to $f_{(2)}$.



The same phenomenon occurs if the vehicle is standing still and the microphone is moving.

The formulas are:

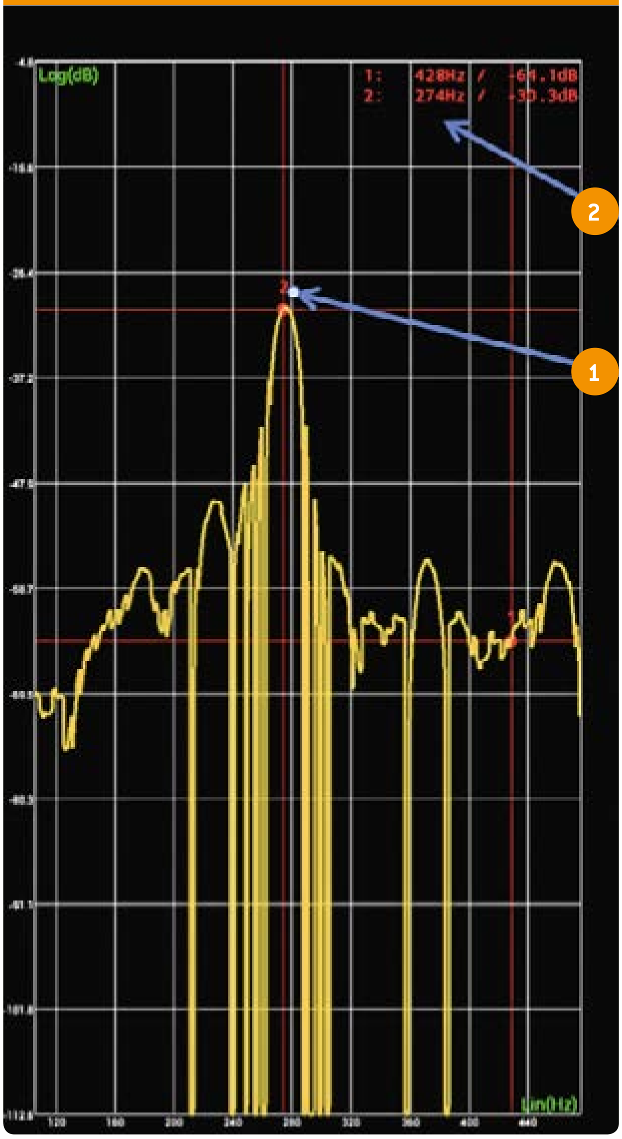
$$f_{(1)}=f_{(0)}\frac{V_{sound}}{V_{sound}-V_{vehicle}}$$

$$f_{(2)}=f_{(0)}\frac{V_{sound}}{V_{sound}+V_{vehicle}}$$

3|3 Measure and analyse the frequency of the sound

This activity requires two smartphones. One will play back the sound emitted by the vehicle, and the other will determine the spectrum of the sound. In the first part of the recorded audio file, the vehicle is moving towards the microphone; in the second part it is moving away from it. While the sound was being recorded, the vehicle was travelling in a straight line at constant velocity (value: v).

FIG.1 Screenshot of Sound Spectrum Analyzer



3|3|1 With Android (FIG. 1)

- Stand in front of the playback smartphone speaker.
- Start the Sound Spectrum Analyzer on the other smartphone.
- Open the menu of the app.
- Start to play back the file.
- After one or two seconds, quickly start the analysis in Sound Spectrum Analyzer (in the menu).
- In the Sound Spectrum Analyzer menu, go to the x-axis and choose log Scale. Do the same with the y-axis.
- With your finger, move the cursor to the first peak (1 in the screenshot).
- Read the frequency from the top right of the screen (2 in the screenshot).
- After you have obtained the first frequency, measure the second frequency.
- To determine the second frequency, follow the same procedure as for the first frequency. The only difference is that you start the SSA analysis just before the end of the recorded audio file.

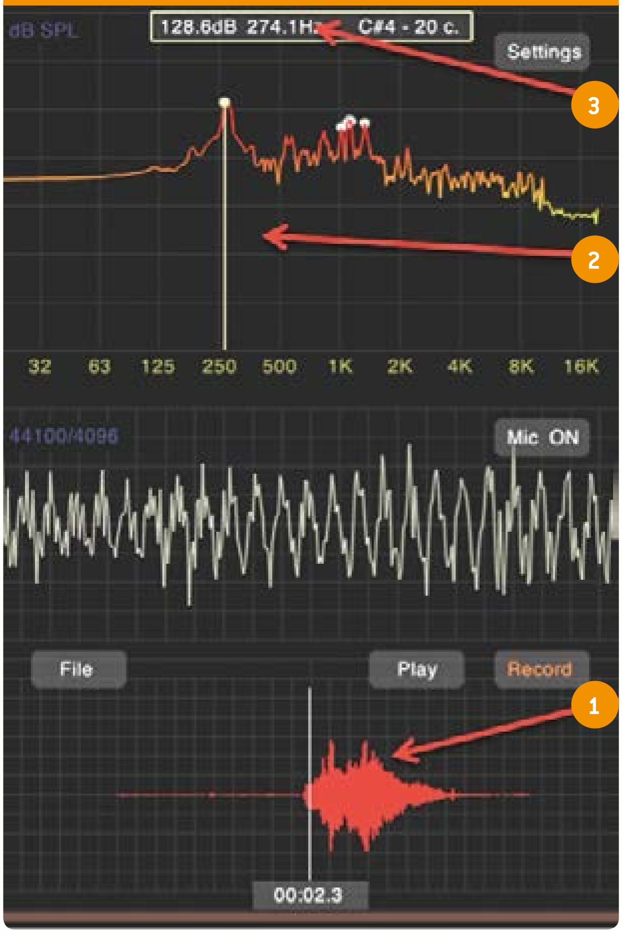
3|3|2 With iOS (FIG. 2)

- Stand in front of the speaker.
- Start iAnalyzer lite on iOS.
- Start to record.
- Start to read the audio file.
- When the audio file is finished, stop the recording.
- The recording of the sound is displayed in the lower part of the screen.
- With your finger, scroll along the audio file (1 in the screenshot).
- The spectrum is displayed in the top part of the screen.
- Touch the screen and scroll to measure the frequency of the sound (2 in the screenshot).
- Choose one frequency peak.
- Measure the frequency (3 in the screenshot) of this peak at the beginning (frequency 1) and at the end (frequency 2) of the recording.

3|3|3 To obtain this speed of the vehicle, use the following formula:

$$V_{vehicle}=V_{sound}\cdot\frac{f_{(1)}-f_{(2)}}{f_{(1)}+f_{(2)}}$$

FIG.2 **Screenshot of iAnalyzer lite**



v=340 m/s is the speed of sound; $f_{(1)}$ is the first frequency; $f_{(2)}$ is the second frequency.

3|3|4 To go further

This formula can be deduced by dividing the formulas of $f_{(1)}$ and $f_{(2)}$

$$\frac{f_{(1)}}{f_{(2)}} = \frac{V_{sound} + V_{vehicle}}{V_{sound} - V_{vehicle}}$$

$$f_{(1)} \cdot (V_{sound} - V_{vehicle}) = f_{(2)} \cdot (V_{sound} + V_{vehicle})$$

$$f_{(1)} \cdot V_{sound} - f_{(1)} \cdot V_{vehicle} = f_{(2)} \cdot V_{sound} + f_{(2)} \cdot V_{vehicle}$$

$$V_{sound} \cdot (f_{(1)} - f_{(2)}) = V_{vehicle} \cdot (f_{(1)} + f_{(2)})$$

$$V_{vehicle} = V_{sound} \cdot \frac{f_{(1)} - f_{(2)}}{f_{(1)} + f_{(2)}}$$

3|3|5 Results

$f_{(1)}$=431.2 Hz; $f_{(2)}$=395.8 Hz

$$V_{vehicle} = 340 \cdot \frac{431{,}2 - 395{,}8}{431{,}2 + 395{,}8}$$

$v_{vehicle}$ = 13.1 m/s; $v_{vehicle}$ = 47 km/h; the speed on the speedometer is 50 km/h.

4| Cooperation option

- Share different files with different velocities and different vehicles and Doppler effect measurements. Make a database of these measurements.
- One school can record its files and send them to another school. The students have to estimate the speed of the vehicle from the other school's recordings.

5| Conclusion

In this teaching unit, the students can follow the described procedure or create their own procedure.

There are other possibilities, for example:

- Come back and find the real frequency $f_{(0)}$ when the vehicle is standing still. For this activity, use the speed of the vehicle, $f_{(1)}$ or $f_{(2)}$.
- Put a buzzer or a smartphone in a fabric bag. For the smartphone, the students first have to start the signal generator app and set it to produce a sinusoidal sound. The maximum sound level should be between 500 Hz and 1 kHz. One student takes the bag and makes vertical circles with the noisy smartphone (be careful not to smash the phone while whirling it around!). Another student records the spectrum of the sound and calculates the radial velocity of the phone using the Doppler effect. This activity can be linked with an activity in which the students search for exoplanets by using the radial velocity method.
- Put a buzzer or a smartphone in front of the pupils. Use the signal generator app to make a sinusoidal sound. The maximum sound level should be between 500 Hz and 1 kHz. One pupil runs with the noisy smartphone and another records the spectrum using another smartphone. You can use the Doppler effect to find the speed of the runner.

6| Further information

- For more information about exoplanets, see http://exoplanets.org/
- Hands-on universe Europe: exercise about exoplanets at euhou.obspm.fr.

Imprint

TAKEN FROM
iStage 2 – Smartphones in Science Teaching
available in English and German
www.science-on-stage.eu/istage2

PUBLISHED BY
Science on Stage Deutschland e.V.
Poststraße 4/5
10178 Berlin · Germany

REVISION AND TRANSLATION
TransForm Gesellschaft für Sprachen- und
Mediendienste mbH
www.transformcologne.de

CREDITS
The authors have checked all aspects of copyright
for the images and texts used in this publication
to the best of their knowledge.

DESIGN
WEBERSUPIRAN.berlin

ILLUSTRATION
tacke – atelier für kommunikation
www.ruperttacke.de

PLEASE ORDER FROM
www.science-on-stage.de
info@science-on-stage.de

First edition published in 2014

SCIENCE ON STAGE – THE EUROPEAN NETWORK FOR SCIENCE TEACHERS

... is a network of and for science, technology, engineering and mathematics (STEM) teachers of all school levels.
... provides a European platform for the exchange of teaching ideas.
... highlights the importance of science and technology in schools and among the public.

The main supporter of Science on Stage is the Federation of German Employers' Associations in the Metal and Electrical Engineering Industries (GESAMTMETALL) with its initiative think ING.

Join in - find your country on
WWW.SCIENCE-ON-STAGE.EU
www.facebook.com/scienceonstageeurope
www.twitter.com/ScienceOnStage

Subscribe for our newsletter:
www.science-on-stage.eu/newsletter

SCIENCE ON STAGE GERMANY
THE EUROPEAN NETWORK FOR SCIENCE TEACHERS

Main supporter
think ING.
Die Initiative für Ingenieurnachwuchs

Proudly supported by
SAP®