

## United Kingdom | Universities and research institutions | Media Ranking



- Physics and Astronomy
  - Physics and Astronomy (miscellaneous)
- Social Sciences
  - Education

IOP Publishing Ltd.

Q2

38

Coverage  
1966-2025

[Home](#) ↗

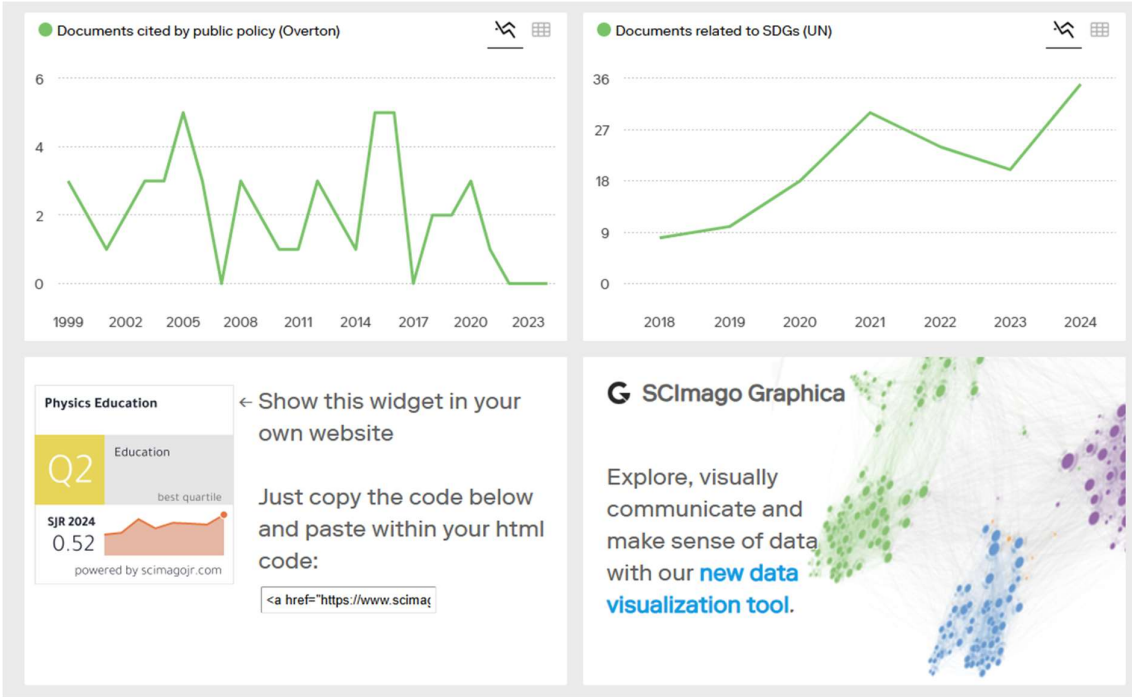
Ads by click

[How to publish in this journal](#) ↗

Physics Education seeks to serve the physics teaching community and we welcome contributions from teachers. We seek to support the teaching of physics to students aged 11 up to introductory undergraduate level. We aim to provide professional development and support for teachers of physics around the world by providing: a forum for practising teachers to make an active contribution to the physics teaching community; knowledge updates in physics, educational research and relevant wider curriculum developments; and strategies for teaching and classroom management that will engage and motivate students.

The heatmap displays the number of publications per year for two categories. The x-axis represents years from 2006 to 2024. The y-axis lists the categories: Education and Physics and Astronomy (miscellaneous). The color scale indicates the number of publications, with red representing low values and yellow representing high values.

| Category                              | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Education                             | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | High | High | High | High | High | High |
| Physics and Astronomy (miscellaneous) | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | Low  | High | High | High | High | High | High |



# Physics Education

[Home](#) > [Journals](#) > [Physics Education](#) > [Editorial board](#)

[Homepage](#)

[Author guidelines](#)

[About Physics Education](#)

[Editorial board](#)

[Track my article](#)

## Editorial board

Editor-in-Chief

Gary Williams Institute of Physics, UK

Deputy Editors

Book Reviews

Clare Thomson British Physics Olympiad, London, UK

Equipment Reviews

John Kinchin The King's (The Cathedral) School (Retd.), Peterborough, UK

Editorial Board

Ian Beddow DCAE Cosford (Retd.), UK

Rosie Boparai St Bede's Inter-church School, Cambridge

Stephanie Grant Norwich School, UK

Mark Harrison King Edward's School, Bath, UK

Judith Hillier University of Oxford, UK

David Housden St Bernard's College, Lower Hutt, New Zealand

Samuel D Koidia Nusrat Senior Secondary School, The Gambia

David R Lapp Tamalpais High School, Mill Valley, USA

Editorial board

Back to top

## Editorial Board

**Ian Beddow** DCAE Cosford (Retd.), UK

**Rosie Boparai** St Bede's Inter-church School, Cambridge

**Stephanie Grant** Norwich School, UK

**Mark Harrison** King Edward's School, Bath, UK

**Judith Hillier** University of Oxford, UK

**David Housden** St Bernard's College, Lower Hutt, New Zealand

**Samuel D Koidia** Nusrat Senior Secondary School, The Gambia

**David R Lapp** Tamalpais High School, Mill Valley, USA

**Stanley Micklavzina** University of Oregon, Eugene, USA

**Shinjiro Ogawa** Waseda University High School, Tokyo, Japan

**Kerry Parker** Wellington High School, New Zealand

**Ann-Marie Pendrill** Göteborg University and Chalmers, Sweden

**Daryl Phillips** Ysgol Bro Pedr, UK

**Damian Pope** Perimeter Institute for Theoretical Physics, Canada

**David Richardson** Clifton College, UK

**Josip Slisko** Benemérita Universidad Autónoma de Puebla, Mexico

**Michael Vollmer** University of Applied Sciences Brandenburg, Germany

**Sihui Wang** Nanjing University, China

### Editorial board

[Back to top](#)

[Back to top](#)

**IOPscience** [Journals](#) [Books](#) [About IOPscience](#) [Contact us](#) [Developing countries access](#) [IOP Publishing open access information](#)

**IOPscience**  [Journals](#) [Books](#) [Publishing Support](#) [Login](#)

## Physics Education



### PAPER

## A simple multimedia resonance experiment for measuring the speed of sound

I E Santosa

Published 17 September 2025 • © 2025 IOP Publishing Ltd. All rights, including for text and data mining, AI training, and similar technologies, are reserved.

[Physics Education](#), [Volume 60](#), [Number 6](#)

Citation I E Santosa 2025 *Phys. Educ.* **60** 065007

DOI 10.1088/1361-6552/ae022c

### Submit

[Submit to this Journal](#)

### Permissions

[Get permission to re-use this article](#)

### Share this article

[Authors](#) [References](#) [Open science](#)

[Article information](#)

[Abstract](#)

[References](#)



## Table of contents for issue 6, volume 60, Physics Education

## Volume 60

Number 6, November 2025

[← Previous issue](#)[Open all abstracts](#)

## Frontlines

## Total work done by a force

063001

Rod Cross

[▼ Open abstract](#)[View article](#)[PDF](#)

## Papers

## OPEN ACCESS

065001

## Do AI-generated videos obey physics laws?

Bor Gregorcic

[▼ Open abstract](#)[View article](#)[PDF](#)

## Using slime to enhance students' understanding of tidal force and its effect on ocean: two water bulges

065002

Somsak Senayai, Thasaneeya Ratanaroutai Nopparatjamjomras, Ratchapak Chittaree and Suchai Nopparatjamjomras

## Focus on Physics in Nature

[▼ Open abstract](#)[View article](#)[PDF](#)

## Temperature mapping in urban biomes using an infrared thermometer: an investigative approach to physics education

065003

Wellington Fabrício dos Santos Costa, Jesuino Alves Martins Júnior, André Flávio Gonçalves Silva, Rosivaldo Xavier da Silva and

Ariel Nonato Almeida de Abreu Silva

[▼ Open abstract](#)[View article](#)[PDF](#)

## Kinetic energy change under Galilean transformation

065004

Leonid Minkin and Anthony C Zable

[▼ Open abstract](#)[View article](#)[PDF](#)

|                                                                                                                                                                                                                                                                                                                      |        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| <b>OPEN ACCESS</b><br><b>Epicycle motion of spinning objects</b><br>Rod Cross<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                                                                                                                                    | 065005 |
| <b>OPEN ACCESS</b><br><b>On Joule's paddle wheel experiment in textbooks II</b><br>Ricardo Lopes Coelho<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                                                                                                          | 065006 |
| <b>A simple multimedia resonance experiment for measuring the speed of sound</b><br>I E Santosa<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                                                                                                                  | 065007 |
| <b>OPEN ACCESS</b><br><b>Investigating the temperature dependence of solar cell open-circuit voltage using Arduino: a multidisciplinary lab experience</b><br>Paolo Frallicciardi, Immacolata D'Acunto and Antonio Di Bartolomeo<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a> | 065008 |
| <b>Developing high school students' experimental competence in radioactivity through problem-based learning</b><br>Ngoc Chat Tran, Hoang Phuong Mai, Van Bien Nguyen and Anh Duc Le<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                              | 065009 |
| <b>Developing high school students' experimental competence in radioactivity through problem-based learning</b><br>Ngoc Chat Tran, Hoang Phuong Mai, Van Bien Nguyen and Anh Duc Le<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                              | 065009 |
| <b>Measuring moment of inertia constants using rolling motion of common household objects</b><br>Edy Wibowo, Nailly Ulya and Putut Marwoto<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                                                                       | 065010 |
| <b>DIY of pencil drawn Seebeck effect</b><br>Aditya Singh Thakur, Shivam Dubey, Abhay Singh Thakur and Rahul Vaish<br><a href="#">▼ Open abstract</a> <a href="#">View article</a> <a href="#">PDF</a>                                                                                                               | 065011 |

| IOPSCIENCE                                                                                            | IOP PUBLISHING                | PUBLISHING SUPPORT    |
|-------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------|
| Journals                                                                                              | Copyright 2024 IOP Publishing | Authors               |
| Books                                                                                                 | Terms and Conditions          | Reviewers             |
|  Conference Series | Disclaimer                    | Conference Organisers |

# A simple multimedia resonance experiment for measuring the speed of sound

I E Santosa 

Department of Physics Education, Sanata Dharma University, Paingan, Maguwohardjo, Sleman, Yogyakarta 55282, Indonesia

E-mail: [edi@usd.ac.id](mailto:edi@usd.ac.id)



## Abstract

The speed of sound was measured using a multimedia-based equipment with a standard setup involving a resonance tube and a smartphone-based sound source. In contrast to conventional methods, the *Phyphox* application was employed to generate sound source and resonance process was recorded using a digital camera. The collected data were analysed using *Praat* to determine time for the resonance condition, and *Tracker* to measure the corresponding air column length. The speed of sound was then calculated graphically from the measured frequency and wavelength. At an ambient temperature of 27.0 °C, the measured speed of sound was found to be  $(346 \pm 2) \text{ m s}^{-1}$ , in good agreement with established reference values. This simple and accessible method is well-suited for educational laboratories, offering students a practical and engaging way to explore wave phenomena using familiar multimedia tools.

Keywords: resonance, multimedia, speed of sound

## 1. Introduction

Measuring the speed of sound is a key topic in wave experiments. The method commonly used is based on the phenomenon of resonance. The equipment consists of a sound source and a resonance tube. The sound source is usually a tuning fork or a loudspeaker with a sound generator. The length of the air column in the resonance tube can be varied to obtain resonance conditions. To detect resonance conditions, one can listen directly. The main task in determining the speed of sound is to obtain the wavelength and frequency of the sound.

The frequency is usually known from the source, for example, a tuning fork, or is measured using a separate frequency meter.

In recent years, a wide range of multimedia tools has been integrated into physics education to enhance data collection and analysis [1–3]. For example, in mechanics, smartphones have been used to measure the speed and acceleration; in optics, cameras combined with *Tracker* software have been used to determine the refractive index [4, 5]. Smartphone has also been applied in experiments involving magnetic field measurements

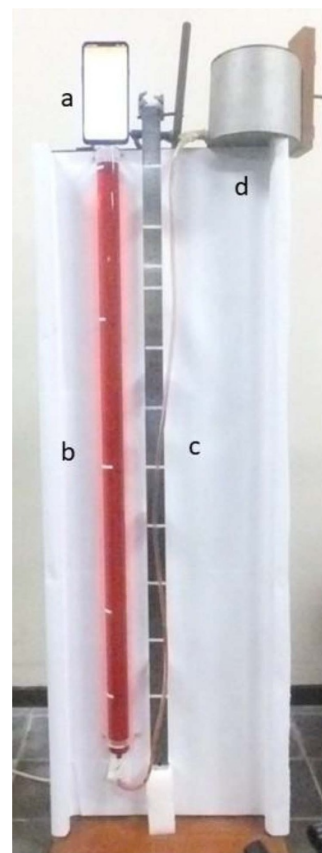
to determine gravitational acceleration [6]. Our experiment takes the innovative use of multimedia tools a step further by employing them to measure the speed of sound through resonance analysis.

Previous studies have demonstrated that the speed of sound can be measured using smartphones [7–9]. One common approach involves a direct time-of-flight method, where the distance travelled by sound and the corresponding travel time—determined using audio analysis software such as Audacity—are measured to calculate the speed of sound. Alternatively, the resonance method has been widely employed due to its conceptual clarity and pedagogical value [10–12]. Bates developed an Arduino-based system incorporating a speaker, a sound level sensor, and a pressure sensor to detect resonance conditions [13]. However, this setup requires the integration of multiple components into a single system, demanding a higher level of technical proficiency from students.

The central aim of this experiment is to simultaneously determine the resonance condition and the corresponding length of the air column in a resonance tube. Typically, this is achieved by gradually lowering the water level in the tube, thereby varying the air column length until resonance is identified by a peak in sound intensity [14]. However, relying solely on auditory observation lacks precision and simultaneity, making it difficult to accurately associate the resonance condition with a specific air column length. To address this limitation, the present study extends previous applications of multimedia tools by employing smartphones and digital cameras to measure the speed of sound through resonance. Unlike earlier methods that required integrating specialised sensors or microcontrollers, this approach enables simultaneous capture of sound intensity and air column length using video recordings and software analysis. This integrated method not only streamlines the experimental procedure but also enhances its suitability for educational settings by providing students with a clear and synchronised visualisation of the resonance phenomenon.

## 2. Experiment

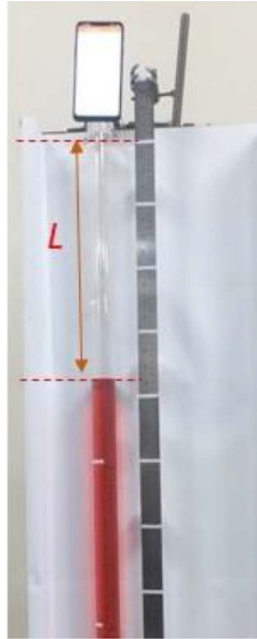
The experimental setup up, depicted in figure 1, consists of a smartphone, a resonance tube, a



**Figure 1.** Experimental setup: (a) smartphone, (b) resonance tube filled with red water, (c) measuring ruler, (d) container.

measuring ruler, and a water container. The smartphone is placed over the mouth of the resonance tube. A measuring ruler attached to the side of the resonance tube is used to measure the length of the air column.

First, the resonance tube was filled with red-colored water nearly to the mouth. Colored water is used in this experiment to create contrast with the background, making it easier to track the position of the water's surface. A smartphone running the *Phyphox* app generated continuous sound at a predetermined frequency. The water level was gradually lowered by placing the container on the floor, allowing water to flow out and lengthening the air column (see figure 2). During this process, the smartphone emits sound continuously. Due to the change in the length of the air column, resonance occurs at certain times, characterised by



**Figure 2.** The length of air column  $L$  was measured from the reference to the water surface in the resonance tube.

an increase in intensity. This entire process was recorded using a digital camera.

The resonance phenomenon will occur repeatedly at a certain length of air column  $L$ , which follows

$$L = (2n - 1) \frac{1}{4} \lambda + \varepsilon \quad (1)$$

with  $n = 1, 2, 3, \dots$

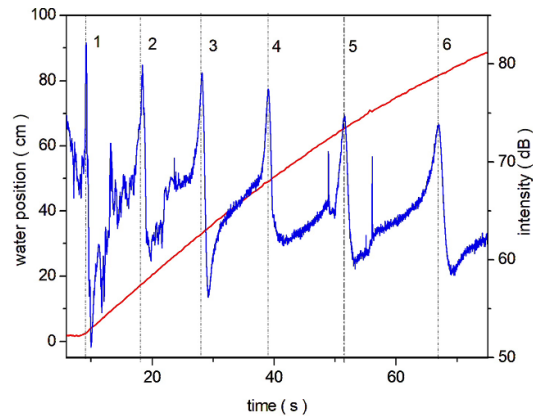
$\lambda$  : wavelength.

An end correction  $\varepsilon$  is added because the actual antinode slightly extends beyond the [14]. Based on equation (1) the true distance between successive nodes, which is half the wavelength, can be determined from the gradient of the graph of  $L$  versus  $n$ . This does not depend on the end correction  $\varepsilon$  and the offset.

For sound with frequency  $f$  and wavelength  $\lambda$ , the speed of sound  $v$  can be determined using the well-known formula

$$v = \lambda f \quad (2)$$

$$\text{or } \lambda = \frac{v}{f}. \quad (3)$$



**Figure 3.** Graph of water surface position (red) and sound intensity (blue). Look at the water position axis on the left side while the sound intensity is on the right side.

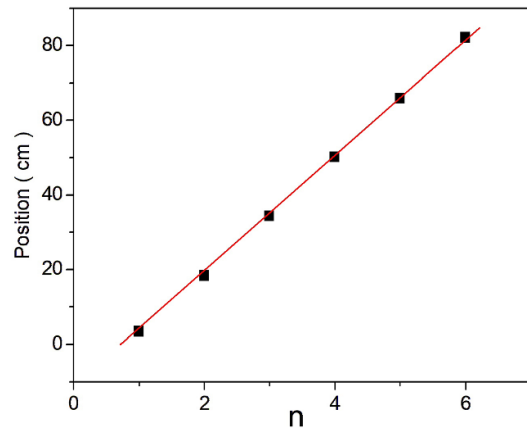
The speed of sound in air depends on the temperature [15]:

$$v = a + b T \quad (4)$$

where  $a = 331.4 \text{ m s}^{-1}$ ,  $b = 0.61 \text{ m s}^{-1} \text{ } ^\circ\text{C}^{-1}$  and  $T$  is the temperature in  $^\circ\text{C}$ .

The video recordings were then analysed to obtain sound data and water level positions during the experiment. We extracted sound data from the videos using a standard free *VLC Media Player* software. This sound file is then analysed using *Praat* software [16]; however, other software, such as *Audacity*, is also suitable for this purpose. This analysis provides intensity data versus time. To obtain the length of the air column, we must track the position of the water surface. We analyse the video to determine the water level position from the reference (figure 2), which is the mouth of the resonance tube using *Tracker* software [17]. The experimental results for a frequency of 1100 Hz at a temperature of  $(27.0 \pm 0.4) ^\circ\text{C}$  are depicted in figure 3.

The experiment lasted about 80 s. In the first 10 s, the noise level was relatively high. Figure 3 shows that at a particular time, the sound intensity increased sharply. This indicates resonance conditions. In this experiment, we observed resonance occurring six times. The second resonance occurred at  $t = 18.38 \text{ s}$ . At this time, the water level position becomes 18.36 cm. By checking the position data at the time of resonance, we



**Figure 4.** Sequential position of water levels from the reference at resonance condition. A solid line is the best linear fit.

**Table 1.** The wavelength of sound at various frequencies.

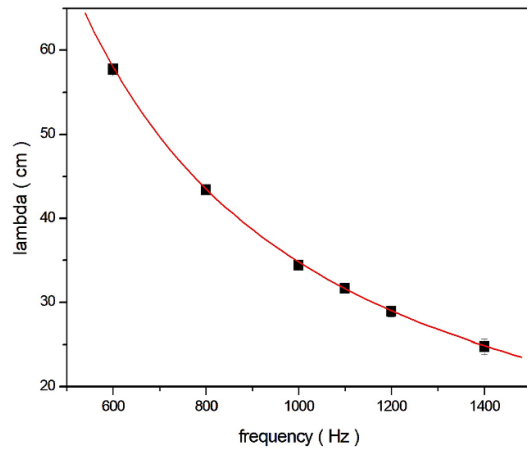
| No | $f$ (Hz) | $\lambda$ (cm) |
|----|----------|----------------|
| 1  | 600      | $57.7 \pm 0.7$ |
| 2  | 800      | $43.4 \pm 0.3$ |
| 3  | 1000     | $34.9 \pm 0.3$ |
| 4  | 1100     | $31.6 \pm 0.1$ |
| 4  | 1200     | $28.9 \pm 0.6$ |
| 5  | 1400     | $24.7 \pm 0.7$ |

can obtain the water level position sequentially, as shown in figure 4.

The position of the water level represents the length of the air column, as in figure 2. The linear fit in figure 4 yields a gradient of  $(15.79 \pm 0.03)$  cm. This gradient describes the distance between two consecutive nodes that produce half the wavelength of the sound, as shown in equation (1). So, the wavelength of the sound with a frequency of 1100 Hz is  $(31.6 \pm 0.1)$  cm.

A similar procedure was applied for various frequencies. The results of the experiment performed at a temperature of  $(27.0 \pm 0.4)^\circ\text{C}$  are presented in table 1 and figure 5.

Figure 5 illustrates that the relationship between wavelength and frequency is not linear but rather an inverse relationship, as described by equation (3). The fitting of figure (5) with an inverse relation gives a fitting coefficient of  $(346 \pm 20 \pm 199) \text{ cm s}^{-1}$  and a correlation of 0.999. This value yields the speed of sound at  $27.0^\circ\text{C}$  to be  $(346 \pm 2) \text{ m s}^{-1}$ . This obtained speed of



**Figure 5.** The sound wavelength,  $\lambda$ , for various frequencies. A solid line represents the best fit for an inverse relationship.

sound is in the range of calculated value using equation (4), i.e.  $v = 347.9 \text{ m s}^{-1}$ .

### 3. Discussion

To determine the speed of sound using the widely known relation, equation (2), both the frequency and wavelength of the sound must be known. In this experiment, the wavelength is obtained indirectly through observation of resonance. It is, therefore essential accurately identify the moment at which resonance occurs. Once a resonance condition is established, the corresponding length of the air column can be precisely determined, allowing for calculation of the wavelength. The sound intensity data presented in figure 3 provides a clear picture. It indicates the occurrence of resonance, enabling us to identify the exact times at which these conditions are met. By correlating these times with the water surface position data, we determine the length of the air column at resonance.

A key feature of this experiment is that the wavelength is derived directly from measurements taken at resonance, ensuring both accuracy and consistency. Accurate determination of the wavelength is a critical aspect of this experiment. It relies on measuring the length of the air column from a node on the water surface to an antinode located just beyond the mouth of the resonance tube. However, in practical implementation, it is not necessary to reference the exact position of

the actual antinode. Instead, we define the water surface position relative to a fixed point at the tip or mouth of the resonance tube. This simplification does not affect the results, as the graphical method used allows for direct determination of the wavelength by analysing the differences between successive resonance positions.

The water surface position is analysed from the video using *Tracker*. In this case, we have placed a standard ruler next to the resonance tube. To minimise the divergence effect, we do not perform a single calibration; instead, calibrations are performed around the actual water position. The experimental results are consistent with published data. The source of uncertainty is primarily due to the determination of the water's surface position. This results in wavelength uncertainties ranging from 0.1 cm to 0.7 cm, as shown in table 1. The average relative uncertainty is about 1.5%.

Our experimental setup is intentionally simple and leverages equipment commonly available in school laboratories, such as resonance tubes. Rather than relying on specialised measurement instruments, the experiment utilises widely accessible devices—namely smartphones and digital cameras—for sound generation and data collection. These multimedia tools are familiar to students, enhancing both engagement and ease of use. Furthermore, the availability of free, open-source software for audio and video analysis supports efficient and cost-effective data processing, making the experiment highly suitable for educational environments.

From a pedagogical perspective, this simple experiment offers valuable educational benefits beyond merely determining the speed of sound. It aligns with the AAPT recommendations for the undergraduate physics laboratory curriculum [18], emphasising core competencies such as modelling, data analysis, and the interpretation of experimental results. Students gain a concrete understanding of acoustic resonance through direct observation and quantitative analysis of sound data.

The experiment encourages the application of theoretical models, including linear fits, to determine the wavelength and the inverse relationships that enable to calculate the speed of sound. These graphical methods provide students with meaningful opportunities to extract physical quantities from diverse data representations,

thereby reinforcing their conceptual understanding and analytical skills.

## 4. Conclusion

The phenomenon of resonance can be effectively demonstrated using standard multimedia devices. The simplicity and accessibility of the setup make this experiment well-suited for implementation in school laboratories. By conducting this experiment, students engage with multiple aspects of experimental physics and enhance their understanding of resonance through the direct observation and analysis of real data.

## Data availability statement

The data cannot be made publicly available upon publication because no suitable repository exists for hosting data in this field of study. The data that support the findings of this study are available upon reasonable request from the authors.

## ORCID iD

I E Santosa  0000-0003-3162-4441

Received 3 July 2025, in final form 19 August 2025

Accepted for publication 1 September 2025

<https://doi.org/10.1088/1361-6552/ae022c>

## References

- [1] Chiaverina C 2022 Performing acoustics experiments using inexpensive Bluetooth speakers and smartphone signal generator applications *Phys. Teach.* **60** 152–3
- [2] Maddur M R, Bhattacharya A and Pathak P 2024 Studying temperature-dependent sound speed in a constantly filling beaker using a smartphone *Phys. Teach.* **62** 487–90
- [3] Gibová Z, Kecer J and Koval'aková M 2025 Laboratory practicals using video recordings of physics experiments *Phys. Teach.* **63** 333–5
- [4] Santosa I E 2021 Measuring refractive index of a liquid with a spherical shape flask and tracker *Phys. Educ.* **56** 065014
- [5] Monteiro M, Cabeza C and Martí A C 2014 Exploring phase space using smartphone acceleration and rotation sensors simultaneously *Eur. J. Phys.* **35** 045013
- [6] Lezcano M S, Gracia E S C D and Mori T J A 2024 Gravitational acceleration—a smartphone approach with the magnetic ruler *Phys. Teach.* **62** 191–3

- [7] Staacks S, Hütz S, Heinke H and Stampfer C 2019 Simple time-of-flight measurement of the speed of sound using smartphones *Phys. Teach.* **57** 112–3
- [8] Hellesund S 2019 Measuring the speed of sound in air using a smartphone and a cardboard tube *Phys. Educ.* **54** 035015
- [9] Hirth M, Kuhn J and Müller A 2015 Measurement of sound velocity made easy using harmonic resonant frequencies with everyday mobile technology *Phys. Teach.* **53** 120–1
- [10] Niu Z J and Luo D 2022 Measurement of the velocity of sound through resonance in air columns as a homemade experiment *Phys. Teach.* **60** 114–6
- [11] Gluck P 2006 Sound experiment uses tall jars and a loudspeaker to demonstrate resonance *Phys. Educ.* **41** 117–8
- [12] Yavuz A 2015 Measuring the speed of sound in air using smartphone applications *Phys. Educ.* **50** 281
- [13] Bates A 2017 A new resonance tube *Phys. Teach.* **55** 544–5
- [14] Armitage E 1982 *Practical Physics in SI* (John Murray)
- [15] Velasco S, Roma F L, González A and White J A 2004 A computer-assisted experiment for the measurement of the temperature dependence of the speed of sound in air *Am. J. Phys.* **72** 276–9
- [16] Boersma P and Weenink D Praat: doing phonetics by computer (available at: [www.praat.org/](http://www.praat.org/))
- [17] Brown D 2008 Video modeling: combining dynamic model simulations with traditional video analysis American Association of Physics Teachers (AAPT) Summer Meeting (available at: [https://physlets.org/tracker/download/video\\_modeling.pdf](https://physlets.org/tracker/download/video_modeling.pdf))
- [18] Kosminski J *et al* 2014 AAPT recommendations for the undergraduate physics laboratory curriculum (available at: [www.aapt.org/Resources/upload/LabGuidelinesDocument\\_EBendorsed\\_nov10.pdf](http://www.aapt.org/Resources/upload/LabGuidelinesDocument_EBendorsed_nov10.pdf))