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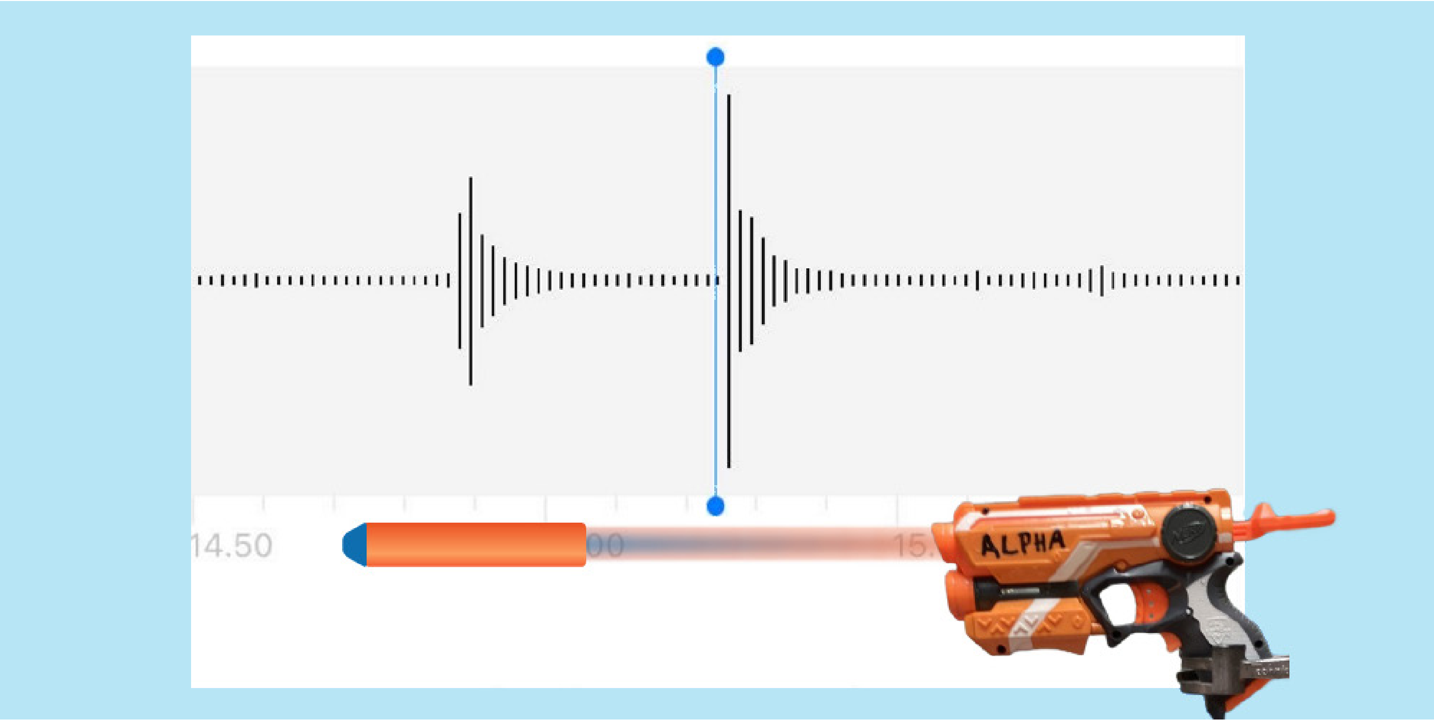

Image courtesy of Chiara Obermüller

Measuring the speed of a toy-gun foam projectile – a handy guide

Matt Cox

Speed of sound: use the sound-recording function of a smartphone to precisely measure a projectile's speed and calculate a safe dodging distance.

The first word I learned in German was Handy, one of the terms used in German for a mobile phone. We have been experimenting with the use of the sound-recording and sound-editing functions common across these handy devices, to generate precise time-of-flight data for foam projectiles from toy guns like Nerf guns.

The voice-record function on a mobile phone is activated with a few simple taps, and in an otherwise silent classroom, the sound of the gun firing and the projectile then hitting its target are recorded. Although difficult to distinguish by ear, these sounds create two clearly defined signals, which can be seen when the mobile phone's sound-file editing function is used. Furthermore, each signal has a time stamp to two decimal places, enabling the time of flight to be calculated with impressive precision.

Here, we describe two activities that make use of this approach. Both activities can be used with students aged 11–16, with adaptations to stretch students of all abilities. Students can explore speed, distance, and time calculations, as well as experimental design and the reliability of data.

Activity 1: Finding the speed of a Nerf-gun projectile

The speed of a Nerf-gun projectile is determined by firing from a known distance at target that will make a noise when hit. Sound-recording and -editing facilities on the mobile phone are used to detect the sound signal and record the time taken between firing the Nerf gun and the projectile hitting the target. From this data, the average speed can easily be calculated.

This can be done as a demonstration in a lesson, or as small groups of students in a science club. It takes 10–20 minutes.

Safety notes

The only significant risk is to the eyes, so safety glasses should be worn by anyone carrying out the experiment or in the area.

Materials

- 1 foam projectile toy gun like a Nerf gun – the type does not matter
- Mobile phone (running on iOS or Android; the iOS Voice Recorder app works well for this experiment; for Android users, the free AudioScope app can be used)
- A target (e.g., a notice board, but anything that makes a sound when hit will do)

Procedure

1. Set up a suitable target. A paper-covered notice board is an ideal target that provides a good sound signal when hit and is large enough that even a novice marksperson will hit it reliably.
2. Mount the gun in a clamp stand.

Image courtesy of the author

3. Place the gun 5 m from the target.
4. Ensure that the classroom is silent.
5. Start the voice recorder.
6. Fire the gun at the target.
7. Stop the voice recorder.
8. Open the editor and select edit recording (on iPhones by tapping on the three little dots).
9. You will now be able to find the time of each signal. The precise sequence of steps depends on your device and software. (On the iPhone, you simply move the sound profile along with your finger, until the desired signal aligns with the blue line. You can then read off the time.)

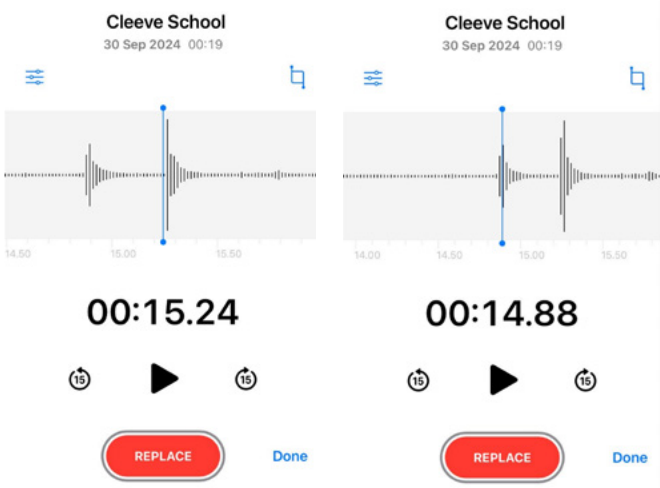

Image courtesy of the author

10. Use the known distance and the time difference between firing and hitting the target to calculate the average speed. A premade [Excel spreadsheet] can be used to log the data.

Results/discussion

The average speed can easily be calculated. In this example, based on a flight time of 0.36 s (15.24–14.88 s) and a distance of 5.0 m, the speed is shown to be 13.9 m/s.

This simple approach can now be used to explore many different ideas relating to speed, distance, time, acceleration, and deceleration. For example, students can investigate how the speed of the projectile changes during flight, by varying the distance to the target. The following data was generated using a small, well-used Nerf gun:

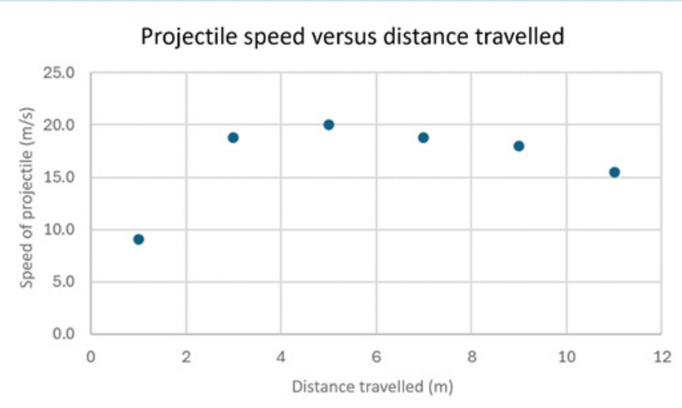

Image courtesy of the author

The data shows how the projectile accelerates for a time after leaving the gun, then gradually loses speed the further it travels. While this does not fit with the underlying physics, the reasons behind this invite further investigation. For example, exploring the uncertainty in the time measurements will lead to a conclusion that the shorter the flight time, the greater the uncertainty.

Activity 2: Target teaser

This activity works best as a classroom demonstration or a small-group experiment in a STEM club. The aim is to determine how far a person holding a target should stand from someone firing a Nerf gun, so they have just enough time to move the target out of the way after hearing the shot.

The speed of the Nerf dart is measured at various distances (as described in Activity 1), and the reaction time – how quickly someone can respond after hearing the Nerf gunfire – is also determined. From these measurements, the minimum distance needed for the person to react and move the target before the projectile reaches them is calculated.

As a demonstration, this activity takes 15 minutes. Alternatively, as a class or group activity, allow 20–30 minutes to complete the activity.

Safety notes

If using a loaded Nerf gun, safety glasses should be worn at all times.

School policies relating to the use of mobile phones should be followed at all times. Any recordings made should be deleted after the lesson. Consider the use of devices owned by your institution, such as tablets or laptops with the appropriate functionality.

Materials

- A Nerf gun or equivalent
- Whiteboard
- Target to aim at
- Clamp stand with boss and clamp
- Sheet of A4 paper
- A mobile phone with sound-recording and -editing functionality

Procedure

1. Place the target against a whiteboard and draw around it to mark its position.

Image courtesy of the author

2. Lower the target until it just clears the outline you've drawn.
3. Position a clamp stand holding a sheet of A4 paper vertically (roughly perpendicular to the floor) at the point where the target just clears the outline.

Image courtesy of the author

4. Practice quickly moving the target from being aligned with its outline to fully outside it, hitting the paper in the process.
5. Set up a smartphone or sound recorder to capture audio.
6. Realign the target with its original outline on the board.
7. Have a second person ready with an (ideally unloaded) Nerf gun.
8. Start the audio recording.
9. The second person fires the unloaded Nerf gun, producing a distinct sound (first signal).
10. The person holding the target reacts by moving it into the paper, producing a second sound.
11. Stop the audio recording.
12. Use the sound trace to measure the time between the two sounds – this is the reaction time.

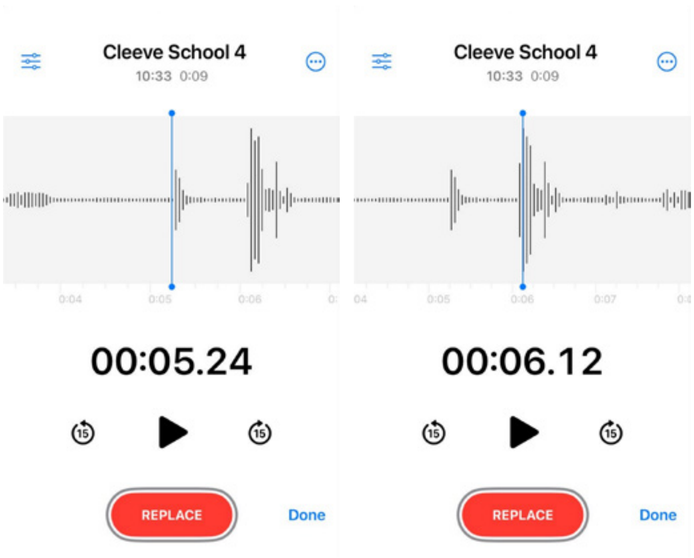

Image courtesy of the author

13. Based on the calculated average projective speed (Activity 1) and reaction time, what is the minimum 'safe' distance at which the target could probably move out of the way in time?

Results/discussion

In our experiments, we found that a reaction time of 0.88 s was typical. For a Nerf-gun bullet travelling at an average speed of 13.9 m/s, the target would need to be a minimum of 13.9 m/s × 0.88 s = 12.2 m for a person to stand any chance of moving the target out of the way before it is hit.

There are many opportunities to explore and evaluate the limitations of this experiment. The following questions can be used to prompt students to plan their own follow-up investigations.

Exploration questions:

- How does the speed of the Nerf dart change as it travels?
- Do different projectiles fired from the same Nerf gun travel at different speeds?
- How much do reaction times vary between individuals?
- Can a person improve their reaction time with practice?
- Does giving a countdown before firing reduce the likelihood of the target being hit?
- Is it reasonable to assume that the person hears the Nerf gun firing instantly?

Optional extensions

Collecting additional data to assess the reliability of results is straightforward – and fun! Students can consider the following questions:

- Does the same combination of Nerf gun and projectile produce consistent results over five trials?
- Do different smartphones record the same flight time for the same shot?
- Are the measured reaction times and flight times normally distributed?

Resources

- Explore the conservation and transfer of energy with Rube Goldberg machines: Ferguson S et al. (2022) Conservation and transfer of energy: project-based learning with Rube Goldberg machines. *Science in School* **56**.

- Teach the concepts of balance and loss of equilibrium through a bridge-building challenge: Curreri M, Gasparini G (2023) Building bridges: how do structures stay upright? *Science in School* **64**.
- Explore the concepts of speed and acceleration using supplied digital images or smartphones: Tarrant J (2023) Moving pictures: teach speed, acceleration, and scale with photograph sequences. *Science in School* **65**.
- Build a Gauss cannon to model linear acceleration and spallation: Lewis J, Michalak L (2024) Build a linear accelerator model. *Science in School* **67**.
- Use sound-detecting robots to explore how sound waves behave in different settings: Ladas V, Stylos G, Kotsis KT (2025) Explore the properties of sound waves by using robotics. *Science in School* **73**.
- Use physics to work out what happens in a car crash and teach about road safety: Hargreaves J (2018) Look out! The physics of road safety. *Science in School* **44**: 34–39.
- Encourage students to think like an engineer and design a glider wing: Holligan B (2015) High flyers: thinking like an engineer. *Science in School* **34**: 36–40.
- Explore how innovations in 3D printing support scientific progress across a variety of fields: Schmidt J et al. (2025) The exciting future of 3D printing. *Science in School* **72**.
- Learn about the risks posed by space debris: Letizia F (2023) Objects in orbit: the problem of space debris. *Science in School* **65**.
- Learn how to distinguish between real and fake astronomical images: Muñoz Mateos JC (2024) CSI Astronomy: learn how to spot fake astrophotography images. *Science in School* **69**.
- Read about how a school ambient air monitoring network detected a pressure wave from a volcano explosion: Barradas-Solas F, Blanco-Gil R (2022) Shaken by the (pressure) waves. *Science in School* **57**.

AUTHOR BIOGRAPHY

Dr Matt Cox MRSC is assistant head for science and STEM at Cleeve School, near Cheltenham in the UK. After completing a PhD in chemistry at Cardiff University in 2007, he moved into secondary school teaching and has taught in the state and independent sectors.