



Subject: Physics

Students: Pupils of the higher commercial school (approx. 16-18 years)

Topic: Measurement of gravitational acceleration with the 'Acoustic stopwatch' of the Phyphox app

Learning objectives:

- **Technical:** The students should experimentally measure the acceleration and understand how the time-distance law is applied to the movement of a falling body.
- **Methodological:** Experimental set-up, data recording and analysis, diagramming, dealing with uncertainties and sources of error.
- **Social:** Teamwork, presentation and discussion of results.

Time: 90 minutes

Materials needed:

- Smartphone or tablet with the Phyphox app installed
- Sphere (preferably made of metal)
- Ruler and pen (both preferably made of metal)
- (Optional) Measuring stick with hook, balloons and needle, metal plate

Description of the lesson/activity:

Introduction (10 minutes)

- Introduction to the topic of "free fall" and gravitational acceleration.
- Explanation of the lesson objective: to measure the fall time of an object using a smartphone and the Phyphox app and to calculate gravitational acceleration.
- Introduction to the "Acoustic Stopwatch" feature in the Phyphox app: The app measures the time between two sounds – the start of the fall and the impact of the object.

Main part (55 minutes)

1. **Preparation and Theory (10 minutes)**



- o Review of the time-distance equation $s = \frac{1}{2} * g * t^2$ for uniformly accelerated motion.
- o Rearranging the formula to calculate acceleration: $g = 2s / t^2$, where s is the fall height and t is the measured fall time.

2. Setting Up the Experiment (5 minutes)

- o Students set up the experiment:
 - A ruler is placed so that it makes a sound when it is knocked away, allowing the ball to start falling.
 - Alternatively, a metal piece is attached to a balloon, and the balloon's neck is popped to produce a sound marking the beginning of the fall.
- o The fall height is measured (between 0.5 m and 2 m).

3. Conducting the Measurements (20 minutes)

- o Students conduct the experiment:
 - They place the ball at the starting position and start the Phyphox app (Acoustic Stopwatch).
 - After the starting sound (e.g., clapping or ruler being knocked away), the fall time is measured until the ball hits the metal plate.
 - The fall height and measured time are recorded.
- o Students repeat the measurement for different fall heights (a total of three to five different heights).

4. Data Processing (20 minutes)

- o Students enter the measured fall times and heights into a table.
- o They create a graph (e.g., fall time vs. height) and analyze how the fall time changes with height.
- o Calculation of the acceleration g for each fall height and comparison with the theoretical value $g = 9.81 \text{ m/s}^2$.

Conclusion (25 minutes)

1. Analysis and Discussion of Results (15 minutes)

- o Students compare their results with the theoretical acceleration and discuss potential discrepancies and sources of error (e.g., air resistance, reaction time).
- o Reflection questions:
 - Why might the experimental value differ from the theoretical value?
 - What sources of error can be expected when measuring fall times?
 - How can measurement accuracy be improved?

2. Summary and Conclusion (10 minutes)

- o The teacher summarises the key findings and discusses how the Phyphox app can serve as a useful experimental tool in everyday situations.
- o Outlook on further experiments related to acceleration or other physical phenomena using Phyphox.

Didactic and methodological notes

- **Differentiation:** The experiment can be adjusted based on students' technical skills – either using a ruler (simple version) or more complex setups like the balloon method.
- **Use of Technology:** The use of smartphones and the Phyphox app allows students to conduct physical measurements easily and quickly, providing a practical application of modern technology.
- **Safety:** During classroom experiments, ensure that falling objects do not pose any danger and that metal plates are safely placed on the floor.