Smartphonics

- Duration : 2 Hours
- The goal of this working lab is to use the **Phyphox app** as a pocket lab to play with physics 😉 while conducting real experiments. Through simple setups involving pendulums, sound, and sensors, you will explore fundamental physical concepts, collect your own data, and analyze it to extract meaningful results, just like a real physicist!
- **Website:** https://phyphox.org/

Lab #1: Measuring Gravity with a Pendulum

1.1 Build the Pendulum:

- Attach a mass (or your phone) to one end of a string (20 to 100cm long) and secure the other end so that the pendulum can swing freely.

1.2 Measure the Length:

- Measure the distance from the suspension point to the center of mass of the weight.

1.3 Record Oscillations:

- Displace the pendulum slightly and release it.
- Challenge: Decide on the best way to measure the period:
  - Use a stopwatch to calculate the average period.
  - Open Phyphox and use your smartphone's accelerometer to record the oscillations and extract the period from the data.

1.4 Repeat for Different Lengths:

- Repeat steps 2 and 3 for various string lengths (e.g., 40 cm, 60 cm, 1m, 2m…).

1.5 Analysis:

- Step 1: If you don't remember the relation between the period of oscillation, the constant g, and the length of the pendulum, refresh your mind by looking online for the formula.

  Pendulum formula→

- Step 2: Based on the formula you found, find the best way to transform and plot your results so that you get a straight-line graph and plot them.

- Step 3: Use the slope of that linear plot to calculate a value for g

1.6 Discussion :

- What are the sources of uncertainty in your measurements?

- Does the amplitude of the oscillation affect your results?

Lab #2: Swinging Sound – Observing the Doppler Effect

2.1 Set Up the Sound Source:

- On one smartphone (the emitter), open the Audio Generator in Phyphox and set it to emit a continuous tone (e.g., between 200 Hz and 1000 Hz).

2.2 Build the Pendulum:

- Suspend the phone (or speaker) securely from the string so that it can swing safely like a pendulum.

2.3 Place the Receiver:

- Set the second phone, running the Audio Spectrum tool, at rest a few meters away, facing the path of the swinging phone (not too close to the swinging path!)

2.4 Swing the Sound Source:

- Displace the pendulum sideways and let it swing in front of the receiver.
- Observe and record the live Audio Spectrum.

2.5 Analysis:

- You should observe the main frequency slightly shifting higher as the source moves toward the receiver, and lower as it moves away — this is the Doppler effect. Try other frequencies if needed.
- Try pausing the recording and analyzing the oscillation of the received frequency over time to estimate the maximum shift in frequency Δf. It might be difficult to see so ask your instructor if needed.

Δf=

- Look online for the Doppler formula for sound in air and try to understand the different terms.

Doppler formula →

- Use the formula and your data to estimate the speed of the pendulum from the observed frequency shift.

v =

2.6 Bonus Question – Cross-check with Classical Mechanics:

- Use your pendulum data (length and period) to estimate the maximum linear speed at the bottom of the swing using classical mechanics:

Lab #3: The Singing Bottle — Exploring Helmholtz Resonance

3.1 Prepare the Resonator:

- Start with an empty bottle.
- Blow gently across the opening until you hear a clear tone. Practice until you can get a stable sound.
- Use Phyphox's Audio Spectrum tool to measure and note the fundamental resonant frequency.

f_0=

3.2 Modify the Air Volume:

- Add a known volume of water to the bottle and repeat the measurement.
- Do this for several different water volumes (e.g., 0 mL, 100 mL, 200 mL, 500mL…). Each time, calculate the air volume left in the bottle.

3.3 Measure Bottle Geometry:

- Measure the length and diameter of the neck of the bottle (important for the Helmholtz formula).

L=

- Estimate or approximate the cross-sectional area A of the neck.

A=

3.4 Analysis

- Step 1: If you don't remember the formula for the resonance frequency of a Helmholtz resonator, look it up online (keywords: "Helmholtz resonance frequency").

Helmholtz resonance formula →

- Step 2: Identify each term in the formula:
  - What quantities are considered as constant in your setup?
  - What is the variable you're changing during the experiment?
  - Which quantity are you measuring?

- Step 3: Use this understanding to determine how to transform your data and plot it in a way that gives you a straight line.

- Step 4: Use the slope of your graph to estimate the speed of sound c_{air} in air.

c_{air}=

3.5 Discussion :

- How consistent is your value for the speed of sound with the expected value (≈ 343 m/s)?

- What assumptions are made in the Helmholtz model? Are they valid here ?

- How could the geometry of the neck would affect you're the frequency ?

- How would using a plastic bottle or a wide-neck jar change the frequency?

- Can you draw an analogy between the Helmholtz resonator and a mass-spring system?
  - What plays the role of the mass?

  - What corresponds to the spring?

  - In physics, the mass-spring model describes a variety of system governed by a differential equation. Can you think of another physical system that behaves like a mass-spring oscillator?

Lab #4: How Tall Are You (According to Physics)?

4.1 Measure the Pressure at Two Heights:

- Stand still and place the phone at floor level for a few seconds. Record the pressure (in hPa or Pa).
- Then raise the phone gently up to the top of your head and hold it there until the reading stabilizes. Record the new pressure.

4.2 Determine the Pressure Difference:

- Compute the difference ΔP between the pressure at your feet and at your head.

ΔP=

4.3 Analysis

- Step 1: Search online for the relation between pressure and altitude. The relevant tool here is Bernoulli's equation or its simplified hydrostatic form.

Bernouilli's equation →

- Step 2: Identify and cancel any terms that are not relevant in your situation.

Simplified Bernouilli's equation →

- Step 3: Rearrange the equation to isolate the height h, and compute your height using:
  - The air density ρ=1.2 kg/m3
  - The gravitational constant g you determined in Lab #1

h=

4.4 Discussion

- How accurate is your height compared to a measurement using a ruler or tape?

- Would this method work well on a windy day outside? Why or why not?

- Could you use this method to estimate the height of a building? Are there any limits ?