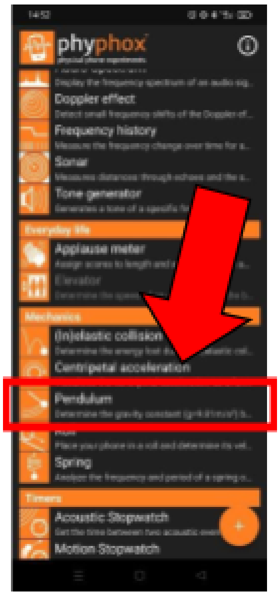
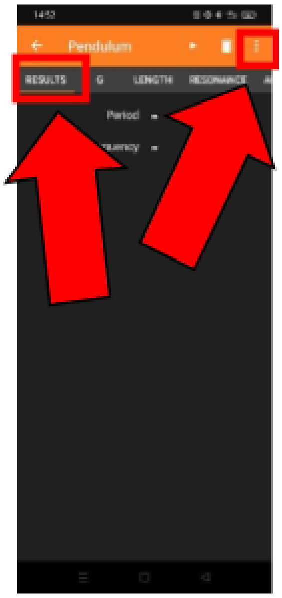
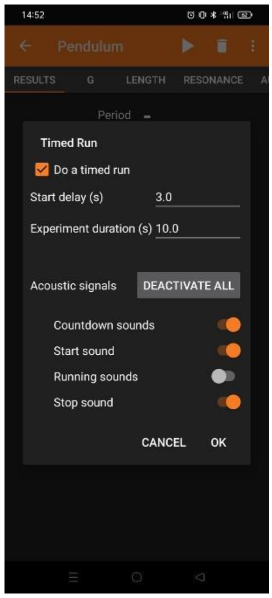
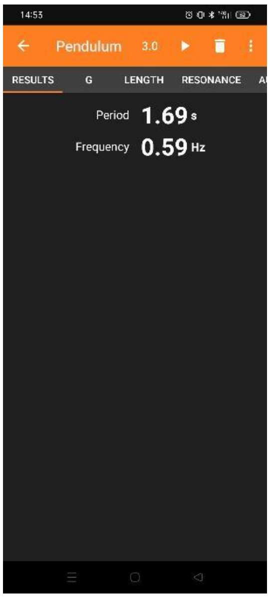
The physics of a pendulum

1. Download Phyphox on your phone
2. Scroll down to ‘Pendulum’
3. Select ‘Timed run’ in the upper right corner
4. Set the start delay and experiment duration to a reasonable value. Activate the acoustic signals to indicate the start and end of the experiment.
5. Put your phone in the transparent bag at the end of the pendulum. Hold the pendulum at a length of your choice. You can use the ruler on the whiteboard to estimate the length. How do you think does the length of the pendulum influence the movement of your phone? Does the weight of your phone have an influence as well?
6. Start the experiment on the phone and initiate an oscillation of the pendulum.
7. Report the measured period T and length l on the whiteboard (or in the comments of Instagram, if not on site in Bern)
8. Looking at the reported measurements of the other people, you think your intuition about the influence of pendulum length and phone weight was correct?









Bonus question:

a) How do you determine the value of the gravitational constant g with this measurement?
b) What are the limitations of this experimental setup? Are there any improvements you can do without a change of the provided hardware and software?

Participate at our Olympiad, deadline for first round participation today! It takes only 40 minutes, and you can solve it online. You can meet peers with similar interests, join several preparation camps and most important have a fun time!

You are too old to participate? Join us as volunteer. Experience once the other side and write the exam tasks yourself instead of solving them, cook for 60 persons in a preparation camp or have a lecture about your favorite topic!

Solution

It is expected that the motion of the pendulum behaves as a harmonic oscillator with a period

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where L is the length of the pendulum and g the gravitational constant of the earth.

This means the longer the pendulum, the longer it takes your phone to move for example form the left-most point to the right-most and back to the left-most point. Note also, that T is independent of the weight of the phone as well as the amplitude of the oscillation. It thus does not matter how exactly you initiate the movement.

Looking at the formula you notice that this very simple experiment even allows you to measure the gravitational constant of the earth. It is sufficient to slightly rearrange the terms:

$$g = \left(\frac{2\pi}{T}\right)^2 L$$

Do you get with your measurement a value close to $g = 9.82\frac{g}{s^2}$?

If not, it may have to be considered that this is a very simple measurement setup. There are several causes for mistakes. There are some simplifications, such as that we assumed that your phone is a point mass. One improvement could be to assume that your phone is box with uniform density. Another improvement that needs no changes to the given formula is taking multiple measurements. Assuming your phone will measure sometimes a bit too low values and sometimes a bit too high values, this will cancel out by taking multiple measurements.

You can do this of course with always the same length of the pendulum. In many experiments it is however more practical or interesting to do measurements with slightly different parameters. In our application we can have a different length of the pendulum in each measurement. We though still want to estimate a single value of g, and not several different values. One common way is linearization of the equation of interest and interpolate all measurements. The value you change ($x = L$) is usually reported on the x axis. We do not apply any transformation on this value. On the y axis we report the value $y = \left(\frac{T}{2\pi}\right)^2$. It is then expected that the interpolation has a slope of $m = \frac{1}{g}$ and no y axis offset. The rearranged formula is

$$\left(\frac{T}{2\pi}\right)^2 = \frac{1}{g}L$$

Did that method improve your result?