Helical spring pendulum with SMARTsense (Item No.: P1002769)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 14-16	Mechanics	Wave properties and oscillations	Helical spring pendulum with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- tablet PC with measureAPP

Experiment Variations:

Keywords:

Hook's law, spring constant, distortion of a spring

Teachers information

The students are to experimentally find out on which quantities the oscillation period of a helical spring pendulum depends. They hereby compare their own experimental results with a given theoretical formulation. The additional task (“the extended evaluation”) enables them to work on a simple and plausible correction to the theoretical results and again compare these with their measurement results. This additional task can also be used to obtain the intraclass variance for the lesson.

Note on set-up and procedure

The force sensor must be tared – this is carried out automatically when the sensor is switched on or off.

Alternatively: Select "Set to zero" and choose the force parameter. Press "save" to tare the force.

Derivation for the formula for the oscillation period T

To derive the formula for T, one must fall back on Newtonian Mechanics $F = m \cdot a$ and Hooke's law $F = -D \cdot s$:

$m \cdot a = -D \cdot s$

With $a(t) = s''(t)$ and the Ansatz $s(t) = s_{\max} \cdot sin(\omega \cdot t)$ follows:

$-\omega^2 m = -D$ or

$$\omega = \sqrt{\frac{m}{D}}$$

with $T = \frac{2\pi}{\omega}$ we get

$$T = 2\pi\sqrt{\frac{m}{D}}.$$

Theory differs here from the measurement: The mass of the spring has not been taken into consideration and neither has the damping of the spring. The spring mass can be taken into consideration by correcting the mass by adding 1/3 of the mass of the spring. A good approximation is then obtained!
It can hardly to be expected that all of the students will understand this correction. This additional task could be given to some of the gifted and capable students in the framework of intraclass variance!

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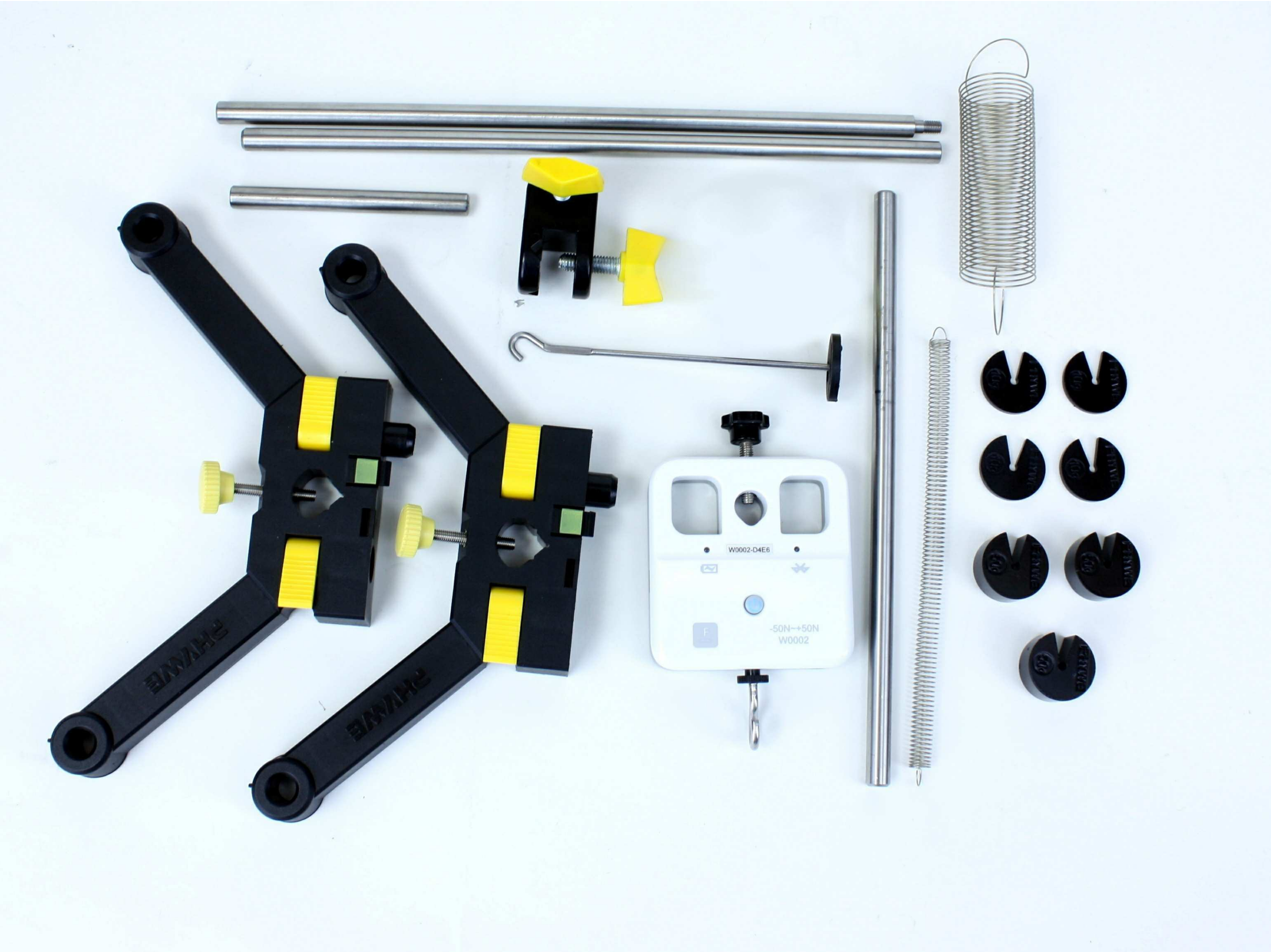
Overview

Introduction

How long does one oscillation period of a pendulum take?

The swings on the playground, the rocking chair in the living room, the pendulum of a grandfather clock – they all have one thing in common: their motion is periodic and therefore repeats itself on and on. Every oscillation takes a certain amount of time – the so called oscillatory period. A spring can also be referred to as pendulum by adding a mass which is displaced from its static position. Within this experiment, you are going to observe the oscillation of a spring pendulum.

Equipment



Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense-Force	12904-00	1
2	Support base variable	02001-00	1
3	Support rod with hole, stainless steel, 10 cm	02036-01	1
4	Support rod, stainless steel, l = 250 mm	02031-00	1
5	Support rod, stainless steel, l = 600 mm, split in 2 rods with screw threads	02035-00	1
6	Boss head	02043-00	2
7	Helical spring D = 3 N/m	02220-00	1
8	Helical spring D = 20 N/m	02222-00	1
9	Weight holder for slotted weights	02204-00	1
10	Slotted weight, 10 g, black	02205-01	4
11	Slotted weight, 50 g, black	02206-01	3
Additional materials:			
12	Tablet PC with "measureApp"		1

Android iPad

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Tasks

1. Determine the dependence of the oscillation period T of a spring pendulum on the displacement s_{max}
2. Determine the dependence of T on the mass m hung on the spring.
3. Determine the dependence of T on the spring constant D.

Setup and procedure

Set-up

- Turn on the Cobra SMARTsense-Force sensor. Open the „measure“ app and select the force sensor.
- Open the diagramm-mode . Select "Sampling rate" in the sensor settings and set it to 800 Hz.
- Set up the experiment as shown in fig. 1 at the edge of a table. Stick the short support rod into the support base as a counter balance. The long rod is fastend in the support base and the boss head added on top. Screw the 100 mm rod to the "SMARTsense-Force" and place the set in the boss head. Make sure all srews are tightend.
- First use the D = 3 N/m helical spring and the weight holder for slotted weights with a total of 4 slotted weights, each of 10 g. Place the holder in the hook of the sensor. Together with the mass of the weight holder, this gives a total mass of m = 50 g. Suspend the spring with the weights from the force sensor in such a way that it can freely oscillate in the room.

Fig. 1: Set up

Procedure

- By turning it on, the force sensor is tared meaning you should read off 0.000 N on your tablet in the display above your diagram. If not select "Set to zero".
- Start with a test run. Displace the spring pendulum vertically so that is can swing freely.
- Start the measurement recording in the app .
- After about 15 complete oscillations, stop the measurement . To be able to use the measured data later on, save the measurement.
- The force of the spring is at minimum at the upper reversal point of the pendulum (no stretching of it by the force of the weight) and at maximum at the lower one (maximum stretching of the spring). The oscillation period T can therefore so be found by determination of the time difference between neighbouring "Force maxima".
- For greater accuracy, determine the time for 10 complete oscillations, for example, the time difference between the 4th and the 14th force maxima. The time determined, divided by ten, gives a sufficiently accurate value for T.
- Use the "Survey" function () to determine the time difference between two oscillation maxima by positioning the two corners of the survey box so that they lie on the appropriate oscillation maxima. The time difference is shown in the evaluation window as "Δx".

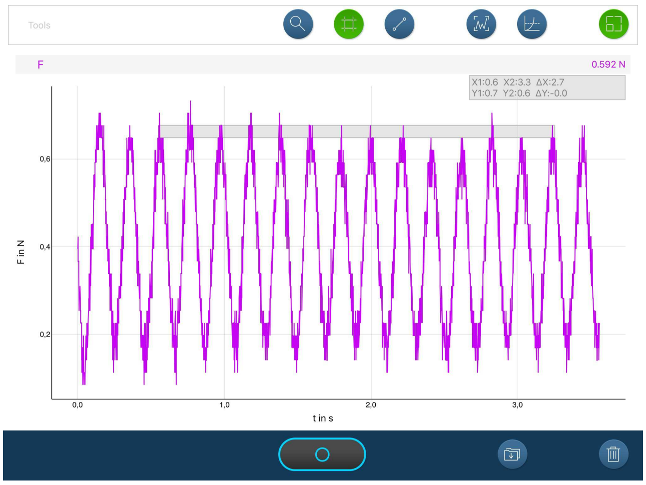


Fig. 2: Determination of the time difference between two oscillation maxima

- For your data analysis later on it is important to keep track of which measurement belongs to which saved data.
- At first, measure the oscillation period of the pendulum depending on the displacement. Use the helical spring with D = 3 N/m and a weight of 50 g. Make three measurements where you change the displacement from 2 cm to 9 cm and 17 cm.
- Now determine the dependence of the oscillation period and the added mass. Start with the helical spring D = 3 N/m and a mass of 20 g. Record a measurement and obtain the oscillation period. Then stepwise add always 20 g to the mass until you have reached 140 g. Enlist all your results for the different oscillation periods in table 1 in the report.
  The change the spring and use D = 20 N/m. Start with 40 g and increase the added mass by 40 g in each step until you reach 200 g. Determine the oscillation period for each step and take down the values in table 1.

Observations and results

Take down your results in the tables in the report. Answer the questions for further evaluation.

Report: Helical spring pendulum with SMARTsense

Result - Question 1 (3 points)

Of 1.: How does the oscillation period depend on the displacement?
To answer this question, determine the oscillation period of the D = 3 N/m helical spring with a hung-on mass m = 50g for three different displacements (2 cm, 9 cm, 17 cm). Measure the time over 10 oscillations.

Result - Table 1 (24 points)

Of 2.: How does the oscillation period depend on the swinging mass?

Determine the oscillation periods *T* with various masses *m*, first only for the *D* = 3 N/m, 20 N/m helical springs (empty spaces in the first and third column). Note hereby that the weight holder itself contributes a mass *m* of 10g!

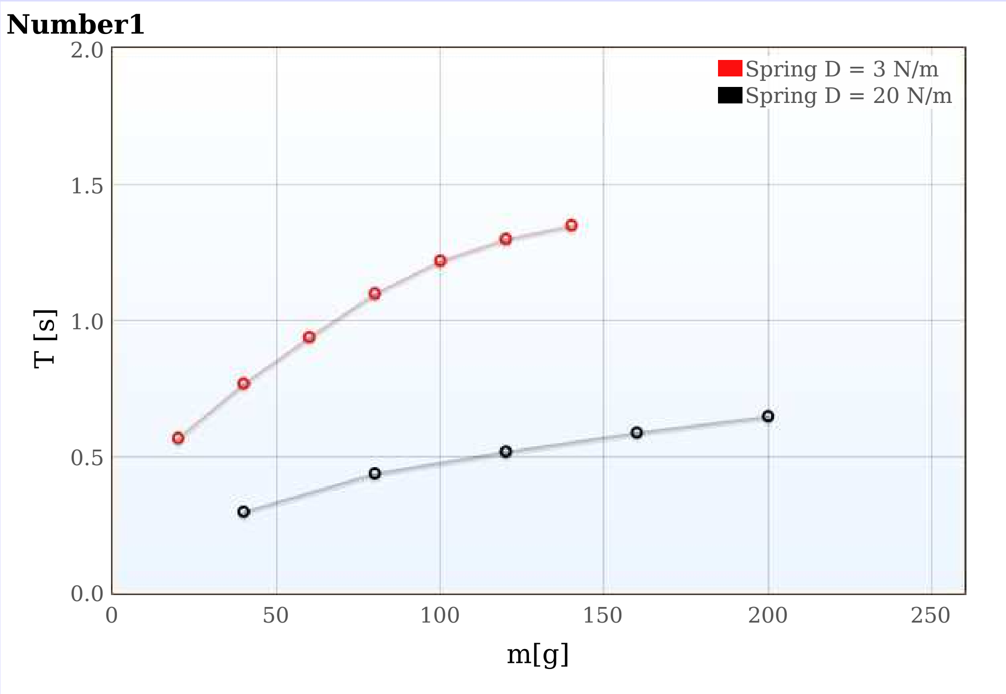
The following mathematical connection is given in theory:

$$T = 2\pi\sqrt{\frac{m}{D}} \, .$$

Use this formula to calculate the oscillation periods and enter them in Table 1 (empty spaces in columns 2 and 4). Pay attention here to give “kg” as the unit (why?)!

Table 1: Oscillation period for various masses *m*

m [g]	T [s] measured D = 3 N/m	T [s] D = 3 N/m	T [s] measured D = 20 N/m	T [s] D = 20 N/m
20	0.57	0.51	-	
40	0.77	0.73	0.30	0.28
60	0.94	0.89	-	
80	1.10	1.03	0.44	0.40
100	1.22	1.15	-	
120	1.30	1.26	0.52	0.49
140	1.35	1.36	-	
160	-		0.59	0.56
200	-		0.65	0.63



Result - Question 2 (1 point)

It can be clearly recognized that the oscillation period is dependent on the swinging mass:
With increasing mass, the oscillation period ....

Result - Question 3 (3 points)

There is no proportional connection here. How can you recognize this from the graph?

....

....

....

....

Result - Table 2 (14 points)

Of 3.: How does the oscillation period depend on the spring constant D?

If you have carefully measured and correctly calculated, you can recognize that the calculated times are systematically too short. The main cause of this is that the mass of the oscillating spring has not been taken into consideration! One cannot simply add the mass of the oscillating spring to m, however, as the upper part of the spring hardly oscillates. A “good approximation” is given by taking 1/3 of the spring mass into consideration (D = 3 N/m: m_{Spring} = 15.3g; D = 20 N/m: m_{Spring} = 7.95g).

Enter $m_{corrected}$ and $T_{calculated}$ (with $m_{corrected}$) in table 2 to check if

$T = 2\pi\sqrt{\frac{m_{korrigiert}}{D}}$ with

$m_{korrigiert} = m + 1/3 m_{Feder}$

is correct.

Table 2 for D=3 N/m

m [g]	$m_{corrected}$ [g]	T_{calc} with $m_{corrected}$ [s]
20	25.1 1	0.57 1
40	45.1 1	0.77 1
60	65.1 1	0.93 1
80	85.1 1	1.06 1
100	105.1 1	1.18 1
120	125.1 1	1.28 1
140	145.1 1	1.38 1

Result - Table 3 (12 points)

Calculate T with $m_{corrected}$ also for the spring with D= 20 N/m

Table 3

m [g]	$m_{corrected}$ [g]	T (with $m_{corrected}$) [s]
40	42.7 1	0.29 1
80	82.7 1	0.40 1
120	122.7 1	0.49 1
160	162.7 1	0.57 1
200	202.7 1	0.63 1
240	242.7 1	0.69 1

Result - Question 4 (2 points)

Did the correction of the theoretical ocillation period improve compared to the measured values? ....

What do you think could also influence the difference between both values? ....