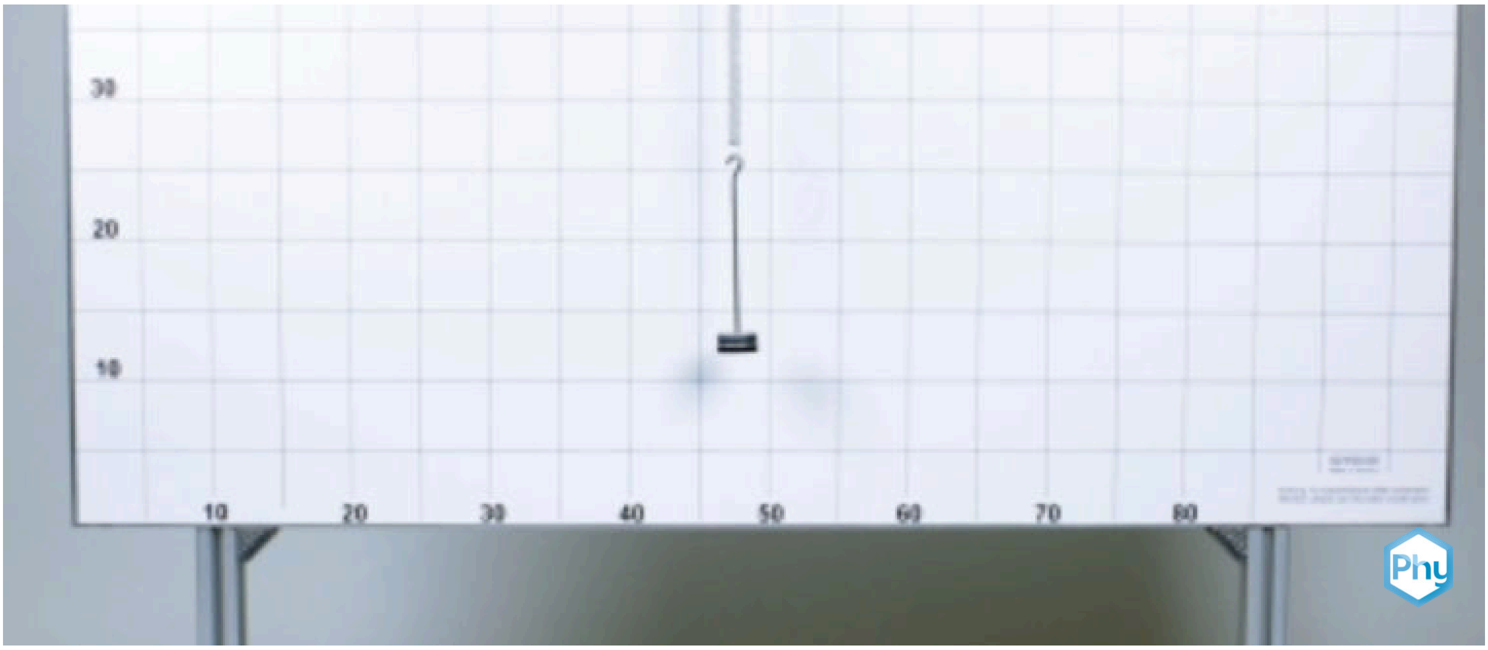
Elastic pendulum



P1254500

Physics | Mechanics | Vibrations & waves

Difficulty level	Group size	Preparation time	Execution time
easy	-	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6672919f62eb6c0002a574d1

General information

Application

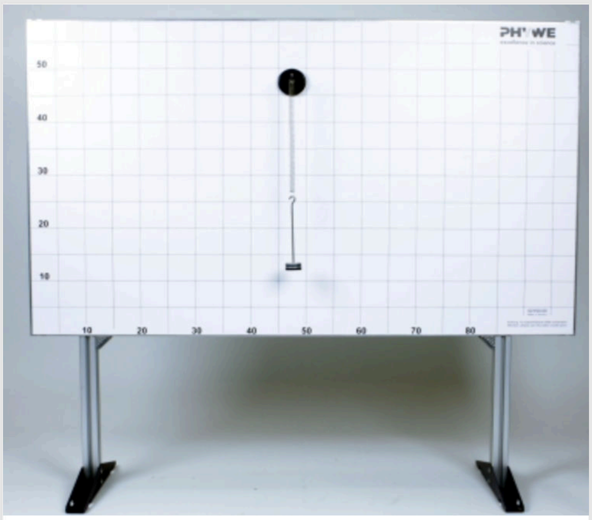


Fig. 1: Experimental setup

An elastic pendulum is a simple mechanical oscillator consisting of a pendulum bob attached to a horizontally moving spring.

Elastic pendulums are used in many areas, e.g. spring oscillators are suspension systems for cars and motorbikes, a tuning fork or a trampoline with a jumper.

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Other information (1/2)

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Prior knowledge

The students should have previous knowledge of "elastic pendulums". It is necessary that the students are already familiar with the concept of the spring constant of the spring.

Principle

The physical variables on which the period of oscillation of a elastic pendulum depends are to be investigated.

Other information (2/2)

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Learning objective

In this experiment, the students are supposed to understand how elastic pendulums work by way of example. The students are also supposed to learn which physical variables can influence the period of oscillation of an elastic pendulum.

Tasks

The students are supposed to measure and observe the period of oscillation of an elastic pendulum under different loads. Finally, the students are supposed to discover the relationship between the period of oscillation and the load.

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Safety instructions

The general safety instructions for experimentation in science lessons apply.

Theory

An elastic pendulum is a simple mechanical oscillator consisting of a pendulum bob attached to a horizontally moving spring.

The period of oscillation is calculated by:

$$T = 2\pi \cdot \sqrt{m/D}$$

m = mass of the oscillating body

D = spring constant of the spring

This leads to the conclusion that the period of oscillation depends on the mass of the pendulum bob and the elastic properties of the spring.

The spring constant describes the ratio of the force acting on a spring and the resulting change in length of the spring.

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Equipment

Position	Equipment	Item no.	Quantity
1	PHYWE Demo Physics board with stand	02150-00	1
2	Hook on fixing magnet	02151-03	1
3	Helical spring, 3 N/m	02220-00	1
4	Helical spring, 20 N/m	02222-00	1
5	Weight holder, 10 g	02204-01	1
6	Slotted weight, silver-bronze, 10 g	02205-03	2
7	Slotted weight, silver-bronze, 10 g	02205-03	2
8	Slotted weight, silver-bronze, 50 g	02206-03	2
9	Slotted weight, silver-bronze, 50 g	02206-03	2
10	Marker, black	46402-01	1
11	Screw clamp	02014-01	2

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Setup and procedure

Setup

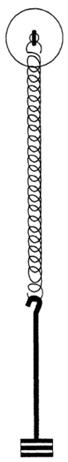

Fig. 2

- Place the hook on the fixing magnet on the demo board.
- Hang the helical spring on the hook with 20 N/m.
- Load the weight holder with four 10 g slotted weights (Fig. 2).

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Procedure

- Pull the weight holder down a few centimetres and release it; measure the time 10 T required for 10 full oscillations and enter the measured value for 10 T in Table 1 (Note: For very fast oscillations, it is advisable to measure 20 T or 30 T and use the resulting value for 10 T.).)
- Gradually increase the load on the weight holder by 50 g and determine the respective value for 10 T and record it in Table 1.
- Instead of the 20 N/m helical spring, hang the 3 N/m helical spring on the hook.
- Load the weight holder with a 10 g slotted weight, trigger the oscillation, measure 10 T and record it in Table 2.
- Gradually increase the load on the weight holder by 20 g at a time and proceed in the same way as before.

Report

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Observation (1/2)

m/g	10 T/s	T/s	T^2/s^2
50	3,3	0,33	0,109
100	4,6	0,46	0,212
150	5,6	0,56	0,314
200	6,5	0,65	0,422
250	7,1	0,71	0,504

Table 1 (helical spring 20 N/m)

Observation (2/2)

m/g	10 T/s	T/s	T^2/s^2
20	5,8	0,58	0,336
40	7,8	0,78	0,608
60	9,4	0,94	0,884
80	10,7	1,07	1,145
100	11,8	1,18	1,392
120	13,0	1,30	1,690
140	13,9	1,39	1,932

Table 2 (helical spring 3 N/m)

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Evaluation (1/7)

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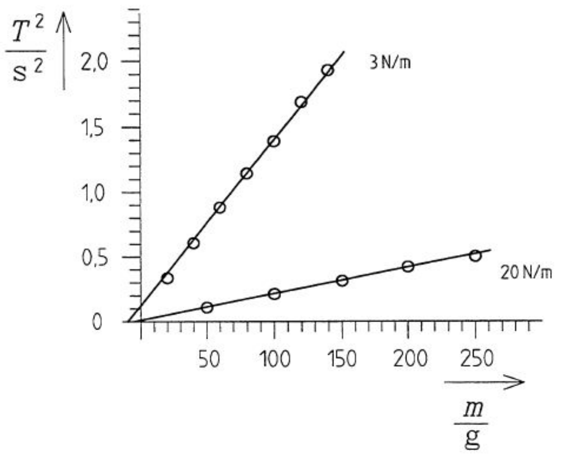

Fig. 3

Firstly, the values for T and T2 are calculated and entered in Tables 1 and 2. In Fig. 3, the square of the period of oscillation is plotted against the mass m. There is a linear correlation in both cases. For the soft spring (3 N/m) in particular, it can be clearly seen that the straight line does not pass through the origin 0. The reason for this is that the masses of the springs are not negligibly small compared to the masses of the differently loaded weight holder (see in particular in Table 2 the lowest m values with the mass of the spring).

Massm_F of the helical springs:

20 N/m: m_F = 5.7g ; 3 N/m: m_F = 15,8 g

Evaluation (2/7)

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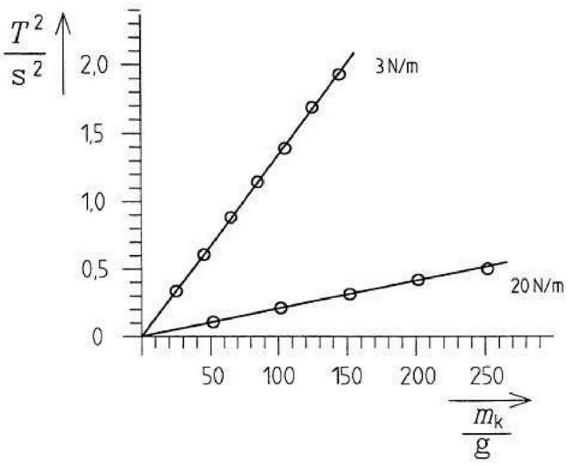

Fig. 4

In order to obtain a proportional relationship (i.e. a representation in which the straight lines run through the origin of the coordinates, see Fig. 4), the mass of the oscillating system must be corrected: one third of the mass of the spring is added to the mass m in each case. The corrected mass used in the further calculation is therefore

$m_k = m + \delta m$ with

$\delta m = 1,9 g$ for the spring with 20 N/m and

$\delta m = 5,3 g$ for the spring with 3 N/m.

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Evaluation (3/7)

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The m_k -values are now calculated in g and kg and entered in Tables 3 and 4.

Finally, the quotients T^2/m_k are calculated. These quotients are constant within the measurement accuracy and have an average value of 2.07 s^2/kg for the spring 20 N/m and for the spring 3 N/m the mean value 13.4 s^2/kg.

In both cases the following applies:

$T^2/m = konstant$ or $T^2 \sim m$.

This proportional relationship can also be seen in Fig. 4. The straight line for the soft spring with 3 N/m is much steeper than the straight line for the hard spring with 20 N/m.

Evaluation (4/7)

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m/g	T^2/s^2	m_k/g	m_k/kg	$\frac{T^2/m_k}{s^2/kg}$
50	0,109	51,9	0,0519	2,10
100	0,212	101,9	0,1019	2,08
150	0,314	151,9	0,1519	2,07
200	0,422	201,9	0,2019	2,09
250	0,504	251,9	0,2519	2,00

Table 3 (hectical spring 20 N/m m_F 5,7 g)

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Evaluation (5/7)

m/g	T^2/s^2	m_k/g	m_k/kg	$\frac{T^2/m_k}{s^2/kg}$
20	0,336	25,3	0,0253	13,3
40	0,608	45,3	0,0453	13,4
60	0,884	65,3	0,0653	13,5
80	1,145	85,3	0,0853	13,4
100	1,392	105,3	0,1053	13,2
120	1,690	125,3	0,1253	13,5
140	1,932	145,3	0,1453	13,3

Table 4 (hectical spring 3 N/m m_F 15,8 g)

The students are now told that the period of oscillation of a spring oscillator can be calculated using the equation

$T = 2\pi \cdot \sqrt{m/D}$

Evaluation (6/7)

Then applies

$T^2/m = 4\pi^2/D$

or

$D = 4\pi^2/(T^2/m)$.

For the hectical spring inserted first, the following applies:

$D = 4\pi^2/(2,07s^2/kg) = 19,1kg/s_2 = 19,1N/m$

and for the second

$D = 4\pi^2/(13,4s^2/kg) = 2,95N/m$

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Evaluation (7/7)

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These values correspond well with the values given in the material list for the spring constants, which in turn have a tolerance due to the manufacturing process.

To summarise, it can be stated that the longer the period of oscillation T of a spring pendulum, the greater the mass m of the oscillating body (system) and the smaller the spring constant $D = F/s$ of the spring.

It applies: $T = 2\pi \cdot \sqrt[2]{m/D}$

and therefore $T \sim \sqrt[2]{m}$

and $T \sim \sqrt[2]{1/D}$.

Remarks

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If, for the sake of simplification, the spring mass is not to be taken into account because the calculation of only one third of the spring mass is not clear to the students, the spring with 3 N/m should not be used because the mass error would be considerably higher than that caused by the measurement inaccuracy.

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Task

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The oscillation period depends on the mass of the pendulum bob.

- True
- False

Check

The oscillation period is independent of the pendulum length

- True
- False

Check

Slide	Score / Total
Slide 22: Multiple tasks	0/2

Total score 0 / 2

Show solutions

Repeat

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