Spring pendulum (Item No.: P1254500)

Curricular Relevance

Area of Expertise: Physik → **Education Level:** Klasse 10-13 → **Topic:** Mechanik → **Subtopic:** Schwingungen und Wellen → **Experiment:** Federpendel

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	1 Student

Additional Requirements:

- Stopwatch

Experiment Variations:

Keywords:

Principle and equipment

Principle

Determine the physical quantities on which the oscillation period of a spring pendulum depends.

Equipment

Position No.	Material	Order No.	Quantity
1	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 for slotted weights	02204-00	1
6	Slotted weight, black, 10 g	02205-01	2
7	Slotted weight, silver bronze, 10 g	02205-02	2
8	Slotted weight, black, 50 g	02206-01	2
9	Slotted weight, silver bronze, 50 g	02206-02	2
10	Marker, black	46402-01	1
Additional material:			
11	Stopwatch		

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Set-up and procedure

Set-up

- Place the hook on fixing magnet onto the demonstration board.
- Hang the helical spring with 20 N/m on the hook.
- Load the weight holder with four 10 g slotted weights (Fig. 1).

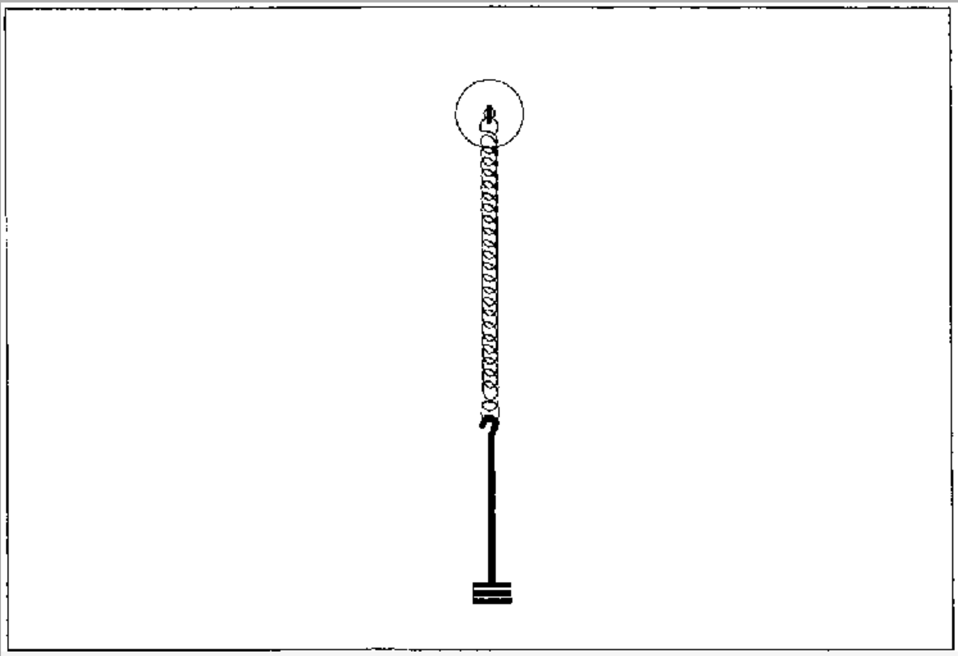

Fig. 1

Procedure

- Pull the weight holder several centimetres downward and release it. Measure the time 10 T required for 10 complete oscillations, and record the measured value for 10 T in Table 1.
  Note: For extremely rapid oscillations it is advis-able to measure 20 or 30 T and to use the value obtained to determine 10 T for the subsequent calculations.
- Progressively load the weight holder in 50 g steps and determine the respective values for 10 T. Record them in Table 2.
- Hang the 3-N/m helical spring on the hook in place of the 20-N/m one.
- Load the weight holder with one 10 g slotted weight, and initiate oscillation: Measure 10 T and record the value in Table 2.
- Increase the load on the weight holder in steps of 20 g each; proceed in the same manner as above.

Observation and evaluation

Observation

Table 1 (20 N/m helical spring)

m/g	$10T/s$	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 2 (3 N/m helical spring)

m/g	$10T/s$	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

Evaluation

To begin with, calculate the values for T and T^2 and record them in Tables 1 and 2. In Fig. 2 the square of the oscillation period is plotted against the mass m. In both cases there is a linear correlation. Especially for the softer spring (3 N/m) on can clearly see that the straight line does not pass through the origin. The reason for this is that the mass of the springs compared to the mass of the variously loaded weight holder is not small enough to be neglected (cf. in particular the smallest m values with the mass of the spring).

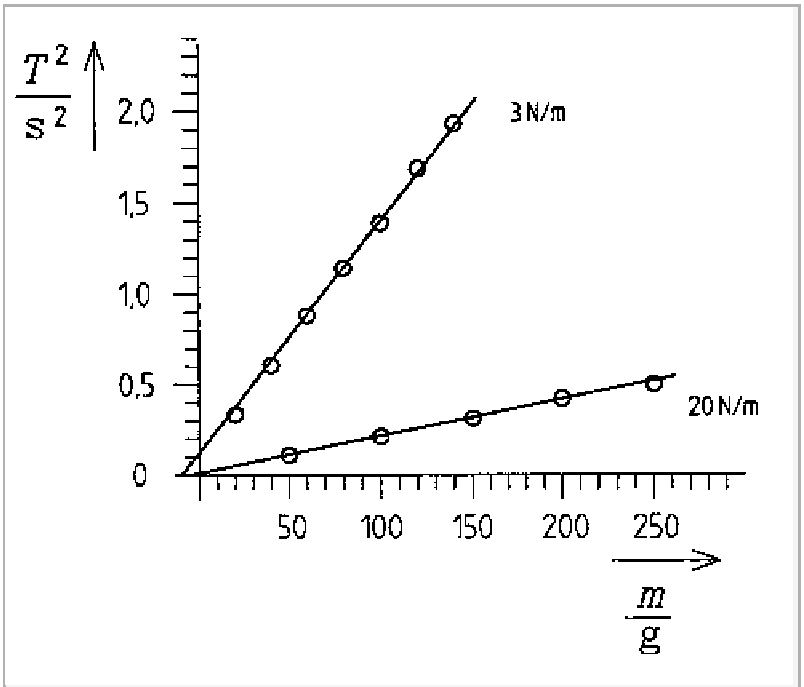

Fig. 2

Masses m_F of the helical springs:

20 N/m: m_F = 5.7g

3 N/m:m_F = 15.8 g

In order to obtain a proportional correlation (i.e. a plot in which the straight lines pass through the ordinate, see Fig. 3), the mass of the oscillating system must be corrected. To do so, add one-third of the mass of the spring to the mass m in each case. The corrected mass which is to be used in the further calculations is thus

$$m_k = m + \Delta m$$

where

Δm = 1.9 g for the 20 N/m spring and

Δm = 5.3 g for the 3 N/m spring.

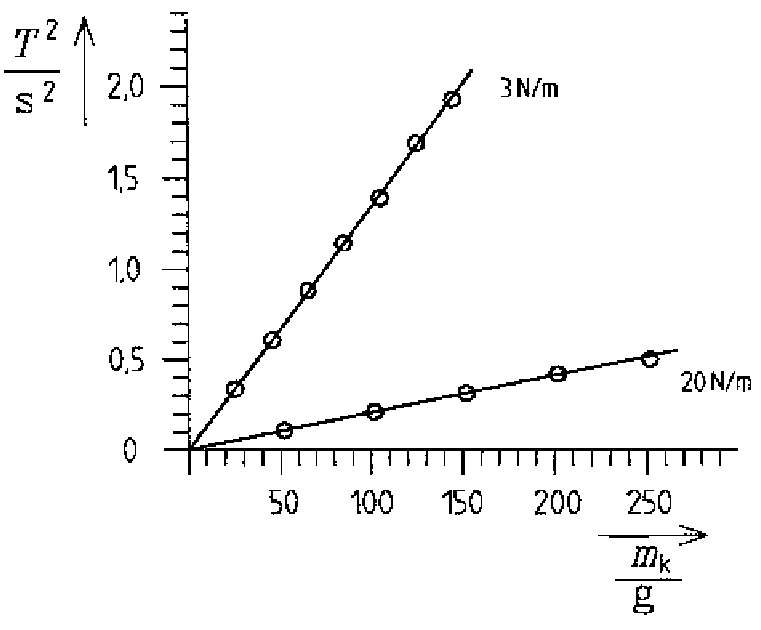

Fig. 3

The m_k values are now calculated in g and in kg; and then recorded in Tables 3 and 4.

Table 3 (20 N/m helical spring, m_F 5.7 g)

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 4 (3 N/m helical spring, m_F 15.8 g)

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

Finally, the quotients T^2/m_k are calculated. These quotients are constants when the measuring accuracy is allowed for and have a mean value of 2,07 s²/kg and a mean value of 13,4 s²/kg for the 3 N/m helical spring.

Thus, in both cases the following is true:

$$T^2/m = constant$$

or

$$T^2 \sim m\,.$$

This proportional correlation can also be seen in Fig. 3. The straight line for the soft, 3-N/m spring has a much greater slope than the straight line for the hard, 20-N/m spring.
The students are now informed that one can calculate the oscillation period of a spring pendulum with the equation

$$T = 2\pi * \sqrt[2]{}m/D$$

Then

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

or

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

For the helical spring used first, it follows that:

$$D = 4\pi^2/(2.07s^2/kg) = 19.1kg/s^2 = 19.1N/m$$

and for the second one:

$$D = 4\pi^2/(13.4s^2/kg) = 2.95N/m$$

These values agree well with the values given in the equipment list for the spring constants, which themselves have a tolerance resulting from their manufacture.

In summary, it can be stated that the larger the mass m of the oscillating body (system) and the smaller the spring const $D = F/s$, the larger the oscillation period T of a spring pendulum. The following is true:

$$T = 2\pi * \sqrt[2]{m/D}$$

and thus

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

as well as

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

Remarks

If, for simplification purposes, it is desired to neglect the mass of the springs because the students have difficulty understanding why only one-third of the springs' mass is considered in the calculation, the 3 N/m spring should not be used since the mass error would be considerably greater than that resulting from the measuring inaccuracy.