Measurement of time (Item No.: P0998200)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 14-16
Topic: Mechanics
Subtopic: Substance and material properties
Experiment: Measurement of time

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

Additional Requirements:

- Scissors

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

The student should count the oscillations of a pendulum while timing them with the aid of a stopwatch. To determine the dependence of the oscillation period on the length of the pendulum is shortened by 50% in the second part of the experiment. The oscillation period of a pendulum is

$$T = 2\pi\sqrt{l/g}$$

where l = Pendulum length and g = 9.81 m/s^2 (acceleration of gravity).

Suggestion

Complete oscillations of the pendulum are counted from the right (or left) reversal point. It is also possible to count them when the pendulum passes through its resting-point.

Remark

The SI time unit is the second (s). It is the base time unit of the SI-system and defined as duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the Cs133 atom.

Conversion

1 day (d) = 24 hours (h) = 1440 minutes (min) = 86400 s.
1 h = 60 min = 3600 s, 1 min = 60 s.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

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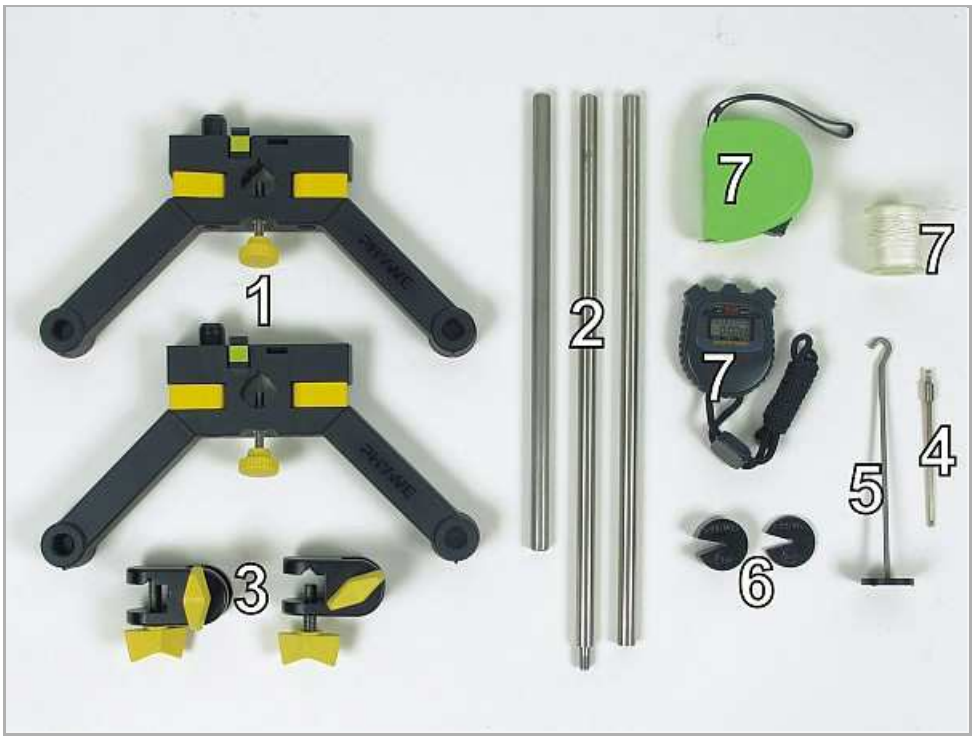
Task and equipment

Task

How rapidly does a pendulum oscillate?

Count the oscillations of a pendulum while timing them with the aid of a stopwatch. To determine the dependence of the oscillation period on the pendulum's length the length is shortened by 50 % in the second part of the experiment.

Equipment



Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
2	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with	02035-00	1
3	Boss head	02043-00	2
4	Holding pin	03949-00	1
5	Weight holder for slotted weights	02204-00	1
6	Slotted weight, black, 10 g	02205-01	1
6	Slotted weight, black, 50 g	02206-01	1
7	Fishing line, l. 20m	02089-00	1
7	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
7	Measuring tape, l = 2 m	09936-00	1
	accessory needed		
	scissors		

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Set-up and procedure

Set-up

Set up a stand for the pendulum. First screw the two rods together (Fig.1). To fix the rod pull the yellow lever (Fig. 2 and Fig. 3).

Fig. 1

Fig. 2

Fig. 3

Secure the holding pin with the upper bosshead so that the hole at its end is horizontal (Fig. 4).

Fig. 4

Tie a piece of fish line (approx. 1.1 m) to the hook of the weight holder (Fig. 5) and thread it through the hole in the holding pin (Fig. 6).

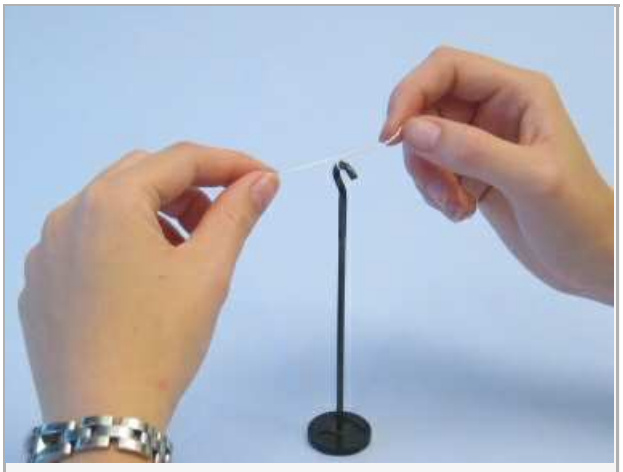

Fig. 5

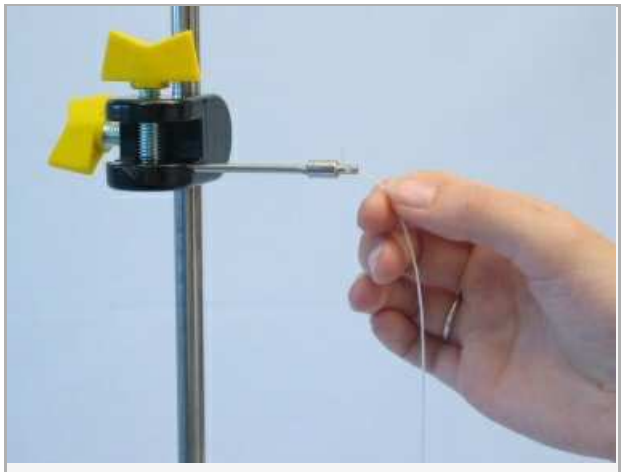

Fig. 6

Tie the fish line to the second bosshead (Fig. 7). Place the weight on the weight holder so that the total weight is 70 g. Fig. 8 shows how to hang the slottet weight into the weight holder.

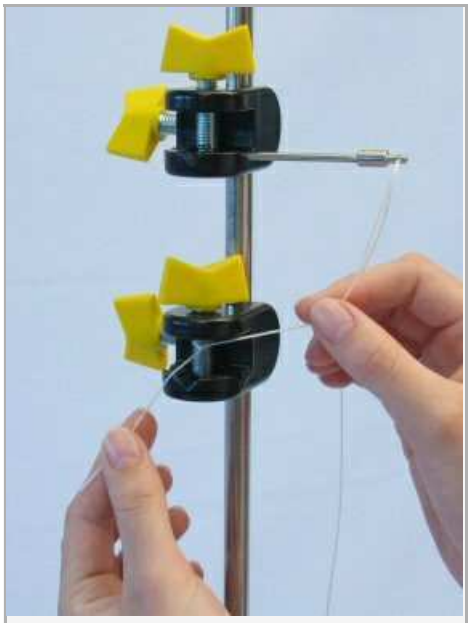

Fig. 7

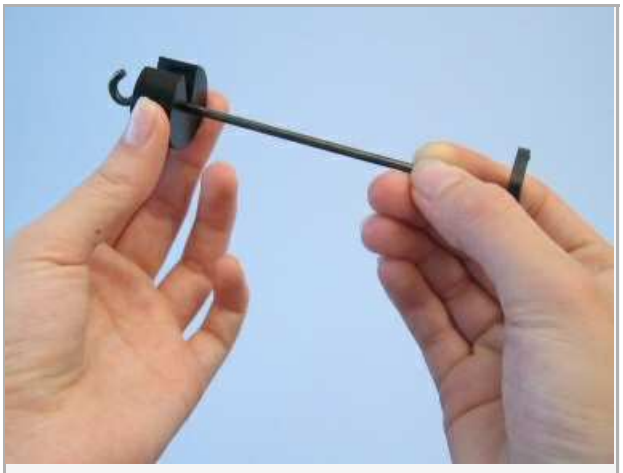

Fig. 8

Adjust the height of the lower bosshead so that the total length from the upper anchor point to the middle of the weights is as close to 99.4 cm as possible. (Fig. 9)

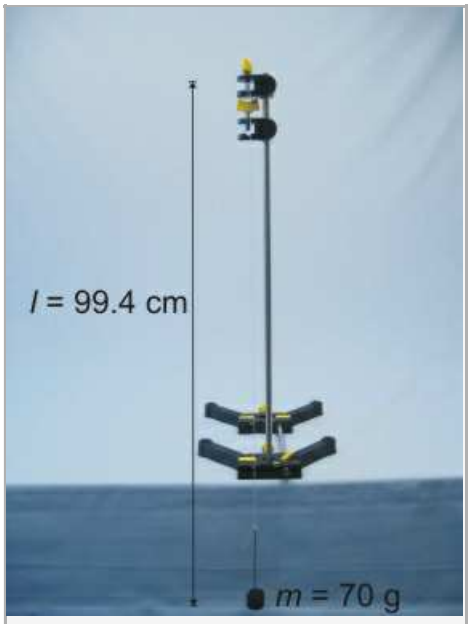

Fig. 9

Procedure

Let the pendulum oscillate parallel to the edge of the table, correct the swing if necessary.

- Move the end of the pendulum about 20 cm laterally (Fig. 10) and release it carefully. On releasing the pendulum, start the stop watch.

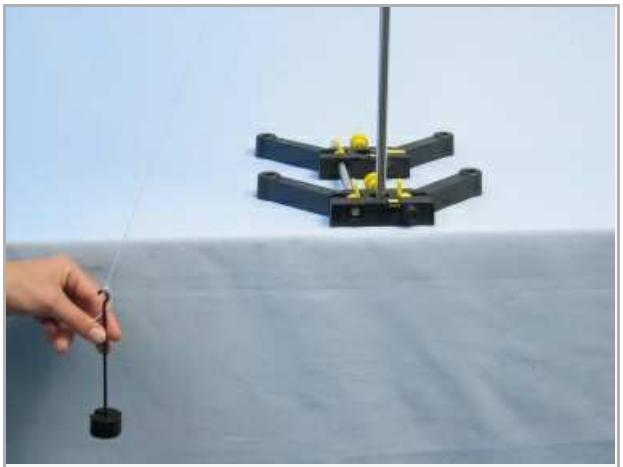

Fig. 10

- Stop the watch when the pendulum has completed an entire oscillation and read the time from the watch. Enter the value obtained under t_1 in Table 1 in the report.
- Repeat the trial by counting 20 oscillations. Stop the watch after 20 oscillations and read the elapsed time; enter the value under t_{20} .
- Repeat both trials 4 more times.
- Shorten the length of the pendulum to exactly 49.7 cm (Fig. 11) by moving the lower bosshead downward and if necessary by winding the fish line around it. Measure the time required for one and for 20 oscillations 5 times each and enter these values in Table 2 in the report.

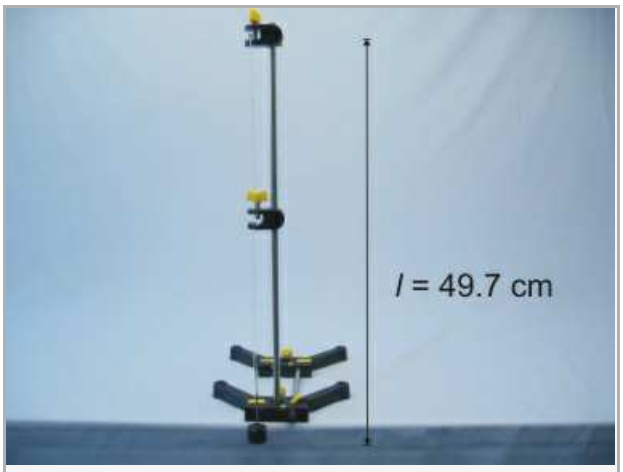

Fig. 11

Report: Measurement of time

Results – Table 1 (12 points)

Enter measured value, which has been measured with pendulum length *l* = 99.4 cm, in the Table.

Calculate the average value (AV) of the time for 1 oscillation (t_1) and of the time for 20 oscillations (t_{20}).

Measuremet No.	t_1 in s	t_{20} in s
1	2.3 $^{1}_{\pm 0}$	40.7 $^{1}_{\pm 0}$
2	2.5 $^{1}_{\pm 0}$	40.5 $^{1}_{\pm 0}$
3	2.2 $^{1}_{\pm 0}$	40.4 $^{1}_{\pm 0}$
4	2.4 $^{1}_{\pm 0}$	40.6 $^{1}_{\pm 0}$
5	2.1 $^{1}_{\pm 0}$	40.3 $^{1}_{\pm 0}$
AV	2.3 $^{1}_{\pm 0}$	40.5 $^{1}_{\pm 0}$

Results – Table 2 (5 points)

Enter measured value, which has been measured with pendulum length *l* = 49.7 cm, in the Table.

Calculate the average value (AV) of the time for 1 oscillation (t_1) and of the time for 20 oscillations (t_{20}).

Measurement No.	t_1 in s	t_{20} in s
1	1.4 $^{1}_{\pm 0}$	28.4 $^{0}_{\pm 0}$
2	1.7 $^{1}_{\pm 0}$	27.1 $^{0}_{\pm 0}$
3	1.6 $^{1}_{\pm 0}$	28.0 $^{0}_{\pm 0}$
4	1.5 $^{1}_{\pm 0}$	27.9 $^{0}_{\pm 0}$
5	1.5 $^{1}_{\pm 0}$	28.3 $^{0}_{\pm 0}$
AV	1.54 $^{0}_{\pm 0}$	27.9 $^{0}_{\pm 0}$

Robert-Bosch-Breite 10
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Results – Table 3

Now calculate the average oscillation time (T) dividing the average of t_{20} by 20. Enter the obtained value T in the Table.

Pendulum length /cm	T/s
99,4	2.025 $^{0}_{\pm 0}$
49,7	1.40 $^{0}_{\pm 0}$

Ergebnis - Tabelle 4

Calculate the period for half an oscillation $t_{0.5}$ from the oscillation period T. Write the values in the Table.

	T/s
$t_{0,5}$ (Pendulum length 99,4 cm)	1.01 $^{0}_{\pm 0}$
$t_{0,5}$ (Pendulum length 49,7 cm)	0.70 $^{0}_{\pm 0}$

Evaluation - Question 1 **(10 points)**

Compare the thus-determined value of T with the average for one oscillation (t_1).

Which result is probably more exact?

The result from the measured time for 20 oscillations (t_{20}) is definitely more exact.

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Evaluation - Question 2 (10 points)

How much do the different measurements diverge from the average value?

The maximum deviation in the measurement example is:

for 1: t_1: 8.7%, t_{20}: 0.5%

for 2: t_1: 10.4%, t_{20}: 2.8%

Evaluation - Question 3 (10 points)

How does shortening the pendulum's length affect its oscillation period?

Shortening the pendulum length by 50% causes a reduction of the oscillation period.

Evaluation - Question 4 (10 points)

Can you explain, why a pendulum with a length of l = 99.4 cm (39.1 in) is called a "seconds pendulum"?

A pendulum of this length passes through the zero point once a second, alternating from the left and from the right. Therefore, it is called a "second-pendulum".

Evaluation - Additional Task 1 (1 point)

Determine the ratio of the oscillation periods of the 2 pendulums of different length. How large is it?

- [x] $\sqrt{2}$
- [x] $3/2$
- [x] 2

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Evaluation – Additional Task 2 (1 point)

Which proportionality is right?

- [x] $T \sim l$
- [x] $\sqrt{T} \sim l$
- [x] $T \sim \sqrt{l}$