Thread pendulum (mathematical pendulum)

Physics → Mechanics → Vibrations & waves

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/5fda46c4b5c96200036a64f5

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Teacher information

Application

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Experimental setup for the investigation of mathematical pendulum

The thread pendulum or also called "mathematical pendulum" is an idealized pendulum. That is, the attached mass m is considered to be point-like, the mass of the pendulum rod or thread is neglected and the pendulum can only perform a movement (oscillation) in a vertical plane. In addition, friction effects and air resistance are also neglected.

The duration of an oscillation T is equal to the reciprocal of the frequency of the oscillation f.

$$T = \frac{1}{f} \ [s]$$

The frequency f in turn results in the quotient of the natural angular frequency ω and 2π.

$$f = \frac{\omega}{2\pi} \ [\frac{1}{s} \triangleq s^{-1} \triangleq Hz]$$

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Other teacher information (1/2)

Prior knowledge

Students should already know the acceleration due to gravity g and its averaged value $9,81\,m/s^2$ as this value plays a major role in relation to the mathematical pendulum.

Scientific principle

The period of oscillation T of the mathematical pendulum is, due to the simplifications, only dependent on the thread length l. The following applies to the period of oscillation T:

$$T = 2\pi \cdot \sqrt{\frac{l}{g}}$$

Other teacher information (2/2)

Learning objective

Using several measurements, students should conclude that mass has no effect on the period of oscillation of the mathematical pendulum. From the diagram they generate, they are to determine that T a function depending on $\sqrt{l}$ is.

Tasks

Students should investigate the mathematical pendulum and for this purpose:

1. Determine the period of oscillation of a string pendulum at different masses and pendulum lengths.
2. Calculate the length of a second pendulum.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Student Information

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Motivation

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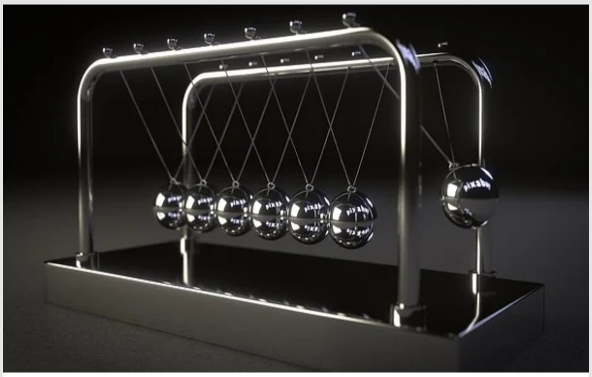

Newton pendulum to illustrate the conservation of energy

Even if you don't always see them directly, pendulums appear in many areas of our daily lives.

Whether the simple Newton pendulum, which is to illustrate the conservation of energy or, for example, the seconds pendulum of large grandfather clocks. Pendulums are used in many areas.

This is also the case, for example, in high-rise buildings located in earthquake-prone areas. Here, the pendulums ensure that the oscillation with which a high-rise building moves due to the excitation by the earthquake is balanced.

Tasks

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In this experiment you will become familiar with the thread pendulum, the so-called mathematical pendulum.

To that end, you will :

1. The period of oscillation T of a thread pendulum for different masses m and pendulum lengths l measure.
2. The length l of a second pendulum.

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
3	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
4	Boss head	02043-00	2
5	Weight holder, 10 g	02204-00	1
6	Slotted weight, black, 10 g	02205-01	4
7	Slotted weight, black, 50 g	02206-01	1
8	Holding pin	03949-00	1
9	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1
10	Measuring tape, l = 2 m	09936-00	1
11	Fishing line, l. 20m	02089-00	1

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Set-up (1/4)

First screw the parts of the support rod together. Connect the two halves of the support base with the 25 cm long support rod and fix them with the locking levers. Insert the 60 cm long support rod into the front support foot and fix it with the holding pin.

Screwing the support rods

Assembling the support base

Place long support rods in the base

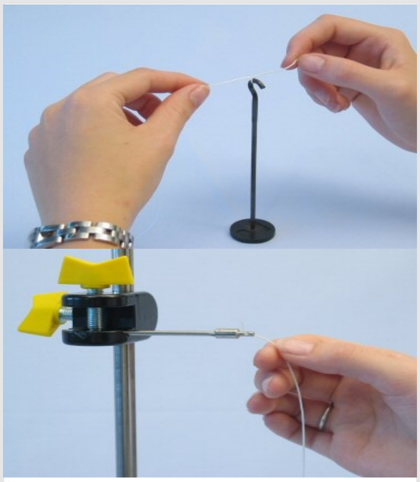
Set-up (2/4)

Fasten retaining bolt to boss head

Attach the first boss head to the support rod and turn the retaining bolt so that the hole is horizontal.

Tie a piece of fishing line (approx. 80 cm) to the hook of the weight plate.

Then pull the second end of the fishing line through the eyelet on the holding pin.



Attach cord to weight plate and holding pin

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Set-up (3/4)

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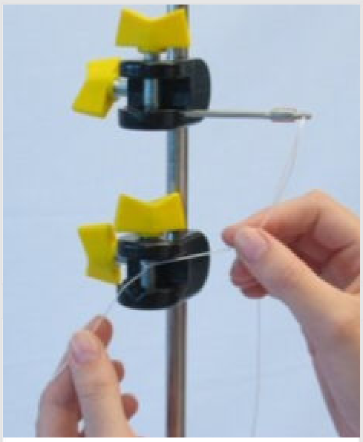

Fasten the fishing line in the second boss head

Clamp the second boss head to the support rod and attach the second end of the fishing line to it.

Place as many weights on the weight plate so that the total mass is 50 g. To attach the slotted weights to the weight plate, slide them over the top of the weight plate.

Mass on weight plate

Set-up (4/4)

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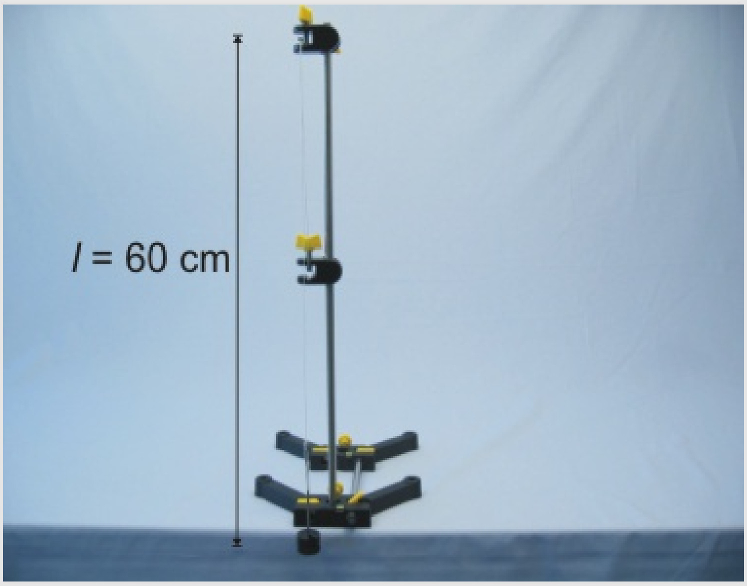

Adjust the height of the lower boss head so that the entire length from the suspension point at the upper end to the centre of the masses is as close as possible to the centre of the masses.
$l = 60\,cm.$

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Procedure (1/2)

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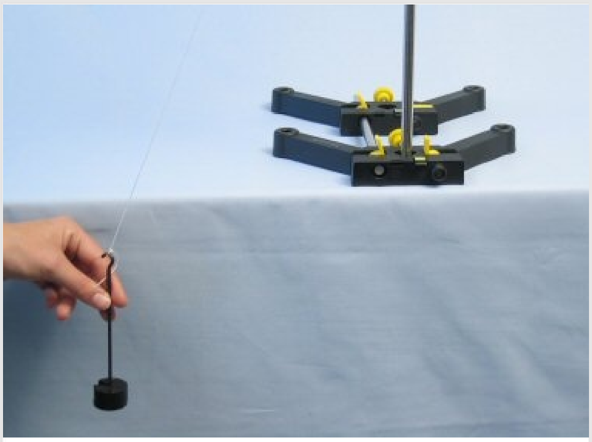

Deflection of the pendulum

- Move the end of the pendulum about 20 cm sideways.
- Gently release the pendulum and start the stopwatch at the same time.
- Determine the time for 10 oscillations of the pendulum.
- Repeat the measurement for 10 oscillations with a total mass of $m = 100\,g$.
- Record the measurement results in Table 1 in the protocol.

Procedure (2/2)

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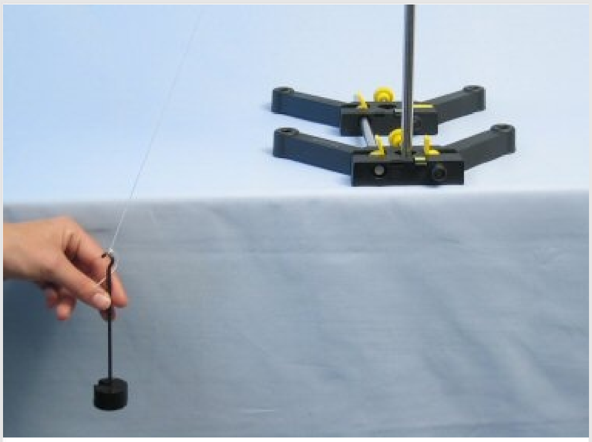

Deflection of the pendulum

- Remove as many mass pieces from the weight plate as required, until the total mass is again $m_{ges} = 50\,g$.
- Now measure the time for 10 oscillations at pendulum lengths of 5, 10, 20, 30, 40 and 50 cm.
- Note: For the short pendulum lengths of 5 and 10 cm, only knot a 50 g mass piece without a weight plate to the fishing line as pendulum mass.
- Record the resulting measurement results in Table 2 in the protocol.

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Report

Table 1

Calculate the square root of the pendulum length $l = 60\,cm$.

$\sqrt{l} =$ ______ $\sqrt{cm}$

Enter your measured values for the mass-dependent measurement in the table and calculate from the time t for 10 oscillations the period of oscillation T for a vibration.

$m\,[g]$	$t\,[s]$	$T\,[s]$
50		
100		

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Table 2

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Enter your measurements from exercise 2 into the table and calculate the square root of the length.

Also enter your measured values for the duration t of the 10 oscillations and calculate from this the period of oscillation T for a vibration.

Add the calculated values to the table.

$l\,[cm]$	$\sqrt{l}\,[cm^{1/2}]$	$t\,[s]$	$T\,[s]$
50			
40			
30			
20			
10			
5			

Task 1

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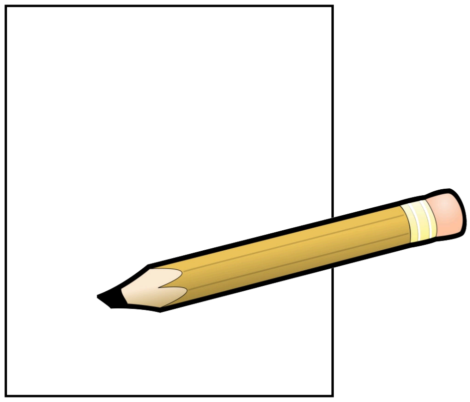

Now take a sheet of paper and draw a diagram on it. In this diagram you put the period of oscillation T (y-axis) as a function of the pendulum length l ($x$axis).

Then draw a second diagram, in which you calculate the period of oscillation T (y-axis) as a function of the root of the pendulum length $\sqrt{l}$ ($x$axis).

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Task 2

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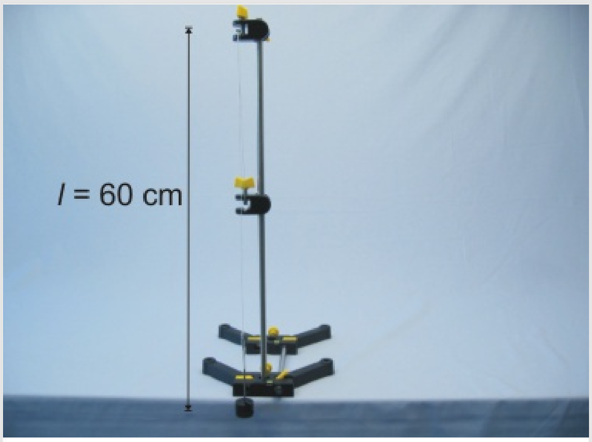

Pendulum length $l = 60\,cm$

If the period of oscillation T dependent on the mass m?

- No, the period of oscillation T is independent of the mass m.
- Yes, the period of oscillation T depends on the mass m.

Check

Task 3

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Experimental setup for the investigation of a mathematical pendulum

Take a look at the graph you generated. The curve represents the behaviour of the period of oscillation T relative to the length of the pendulum l depicted. How does the pendulum length affect the period of oscillation?

- The shorter the pendulum length, the greater the period of oscillation.
- The pendulum length has no influence on the period of oscillation.
- The longer the pendulum length, the greater the period of oscillation.

Check

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Task 4

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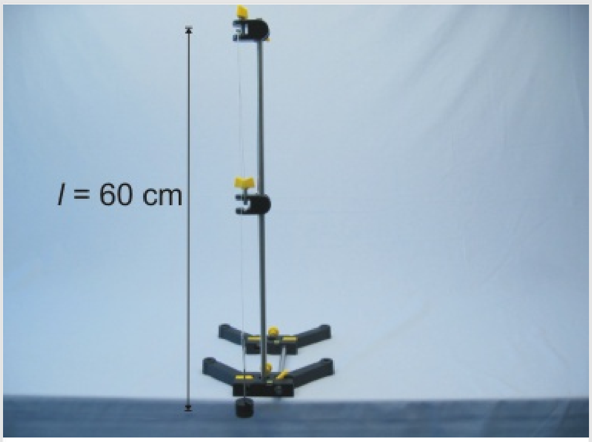

Pendulum length $l = 60\,cm$

Infer the correct dependence for the period of oscillation on the length of the pendulum from the diagrams you have created:

- $T \sim \sqrt{l}$
- $T \sim l$
- $\sqrt{T} \sim l$

Check

Task 5

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Experimental setup for the investigation of a mathematical pendulum

Calculate from the diagram the proportionality factor K and compare it with the value you get if you $2\pi/\sqrt{g}$ ...and do the math. Do the two values match?

- No, the value for K is much smaller.
- No, the value for K is much larger.
- Yes, the two values match very well.

Check

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Task 6

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Experimental setup for the investigation of mathematical pendulum

What dimension has K?

- s/m
- $\sqrt{s/m}$
- $\sqrt{m}/s$
- $s/\sqrt{m}$

Check

Task 7

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Using the given and calculated quantities, set up the oscillation equation for the string pendulum. Which is the correct formula?

- $T = \sqrt{2\pi} \cdot \frac{l}{g}$
- $T = 2\pi \cdot \sqrt{\frac{g}{l}}$
- $T = 2\pi \cdot \sqrt{\frac{l}{g}}$
- $T = 2\pi \cdot \frac{l}{g}$

Check

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Task 8

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Calculate the pendulum length for a thread pendulum which has an oscillation period of 2 s (seconds pendulum, time for half an oscillation = 1s):

$l =$ [ ] cm

Calculate the acceleration due to gravity g from your measurement data using the proportionality factor determined:

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

$g =$ [ ] m/s^2

Slide	Score / Total
Slide 20: Independence \(T\) From \(m\)	**0/1**
Slide 21: Dependence \(T\) From \(l\) (1)	**0/1**
Slide 22: Dependence \(T\) From \(l\) (2)	**0/1**
Slide 23: Comparison of \(K\) and \(K'\)	**0/1**
Slide 24: dimension of \(K\)	**0/1**
Slide 25: Formula of the thread pendulum	**0/1**

Total **0 / 6**

Solutions Repeat Export text

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