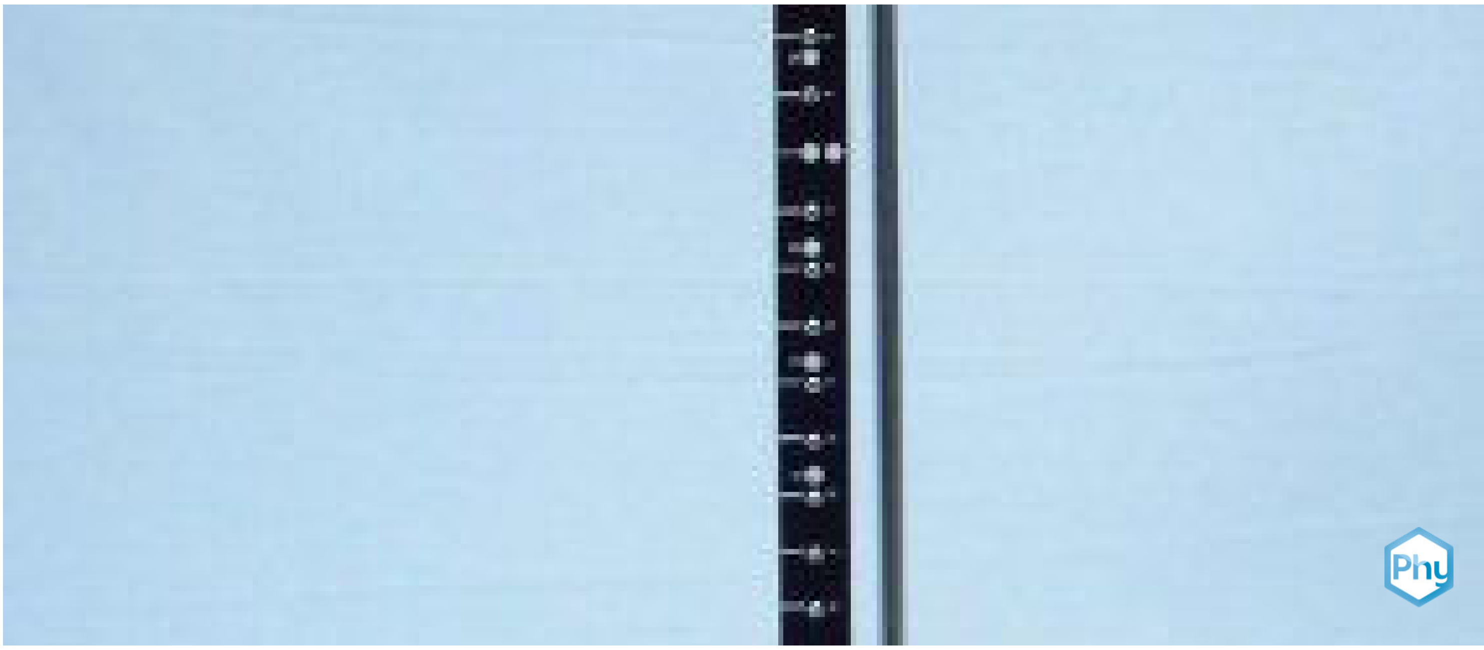
Reversible pendulum (physical pendulum)



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/5fda7ec4b5c96200036a66f0

Teacher information

Application

Experimental setup for the investigation of the reversion pendulum

The reversion pendulum is mostly used to determine the position-dependent acceleration due to gravity. A rigid body is generally used for this purpose and there are clear parallels to the thread pendulum (mathematical pendulum).

The name reversion pendulum is based on the fact that to certain suspension points in the distance s_1 to the centre of gravity another suspension point opposite to the centre of gravity with distance s_2 which has exactly the same period of oscillation. In particular, there is a point with a minimum oscillation period.

The suspension point s_2 and thus the so-called reduced pendulum length $\lambda_R := s_1 + s_2$ result from the comparison of the periodic times of mathematical and physical pendulums (see derivation).

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Other teacher information (1/4)

Prior knowledge

The students should already have completed the experiment on the thread pendulum (mathematical pendulum) in order to have understood its functional principle and the physical relationships behind it.

Scientific principle

Any body with mass m with moment of inertia J_A about a horizontal axis A is rotatably suspended, which does not pass through the centre of gravity (distance s), is a physical pendulum and performs at small deflection φ of harmonic oscillations around the rest position. In small-angle approximation, the following equation of motion applies with the resulting periodic time T:

$$J_A \cdot \ddot{\varphi} = -m \cdot g \cdot s \cdot \varphi \quad \Rightarrow \quad T = 2\pi\sqrt{\frac{J_A}{m \cdot g \cdot s}}$$

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Other teacher information (2/4)

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Learning objective

In the present experiment, the students should recognize the special properties of a reversion pendulum and, in particular, understand the significance of the so-called reduced pendulum length on the basis of their measurements.

Tasks

Students are to investigate the natural frequency of a thread pendulum and for this purpose:

1. Measure the time for 10 oscillations of the reversion pendulum and determine the resulting period.
2. The time for 10 oscillations of the thread pendulum with the reduced pendulum length corresponding to the test λ_R measure.

Other teacher information (3/4)

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The so-called **reduced pendulum length** λ_R results by definition from the comparison of the period of a string pendulum with that of the physical pendulum. For the latter, it must be taken into account that it is a body (moment of inertia J_S, ground m), which is by far the most s_1 axis of rotation shifted relative to the center of gravity A possesses. With Steiner's theorem ($J_A = J_S + ms_1^2$) the following results:

$$T_1 = 2\pi\sqrt{\frac{J_A}{m \cdot g \cdot s_1}} = 2\pi\sqrt{\frac{1}{g} \cdot \left(\frac{J_S}{m \cdot s_1} + s_1\right)} \equiv 2\pi\sqrt{\frac{\lambda_R}{g}} \quad \Rightarrow \quad \lambda_R = \frac{J_S}{m \cdot s_1} + s_1$$

λ_R is by definition greater than s_1. Inserting the suspension point defined by the reduced pendulum length $s_2 = \lambda_R - s_1$ with successive substitution of the definition of λ_R provides the same period duration:

$$T_2 = 2\pi\sqrt{\frac{1}{g} \cdot \left(\frac{J_S}{m \cdot (\lambda_R - s_1)} + (\lambda_R - s_1)\right)} = \ldots = 2\pi\sqrt{\frac{1}{g} \cdot \left(\frac{J_S}{m \cdot s_1} + s_1\right)}$$

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Other teacher information (4/4)

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The points thus occur in pairs along the body axis.

If, for example, one considers the suspension point at the end of a rod with length L and homogeneous mass distribution (approximately applies for the lever used in this experiment), i.e. $s_1 = L/2$ the moment of inertia is approximately the same:

$$J_{L/2} = \frac{1}{12}mL^2 + m \cdot \left(\frac{L}{2}\right)^2 = \frac{1}{3}mL^2$$

This results in the reduced length λ_R to:

$$\lambda_R = \frac{J_S}{m \cdot L/2} + \frac{L}{2} = \frac{L}{6} + \frac{L}{2} = \frac{2}{3} \cdot L$$

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

Motivation

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Free fall during parachute jump

The acceleration due to gravity is often referred to as a constant. $g = 9,81 m/s^2$ is given. In fact, this is a location-dependent variable and thus varies at different points on the earth's surface. Gravity acceleration at other planets thereby reaches from $3,70\,m/s^2$ on Mercury all the way to $24,79\,m/s^2$ on Jupiter. On the moon it is even only $1,62\,m/s^2$.

In particular, the acceleration due to gravity decreases sharply with increasing distance from the earth's surface. Thus, conversely, it increases continuously during parachuting.

A precise method of determining the position-dependent acceleration due to gravity is with the help of the so-called reversible pendulum. In this experiment, you will learn about the properties of this 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	Boss head	02043-00	1
4	Lever	03960-00	1
5	Holding pin	03949-00	1
6	Weight holder, 10 g	02204-00	1
7	Slotted weight, black, 10 g	02205-01	1
8	Slotted weight, black, 50 g	02206-01	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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Additional equipment

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Position	Equipment	Quantity
1	Scissors	1

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Set-up (1/2)

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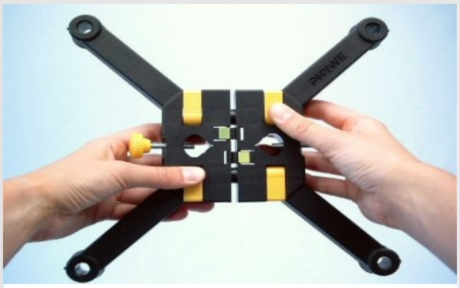
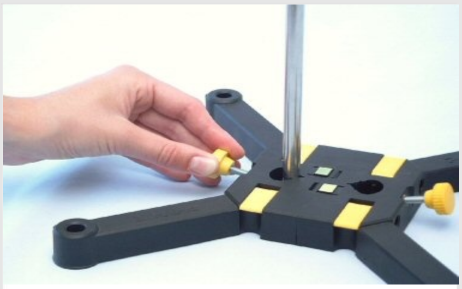
First screw the split support rod together and assemble the support base.

Place the support rod in the support base and secure it with the screw.

Screwing the support rod



Assemble support base



Attaching the support rod

Set-up (2/2)

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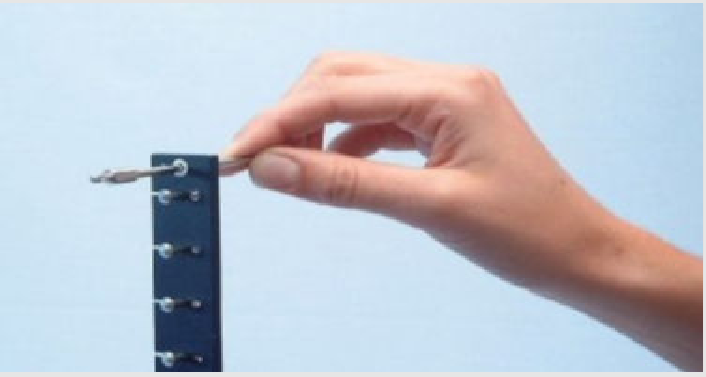
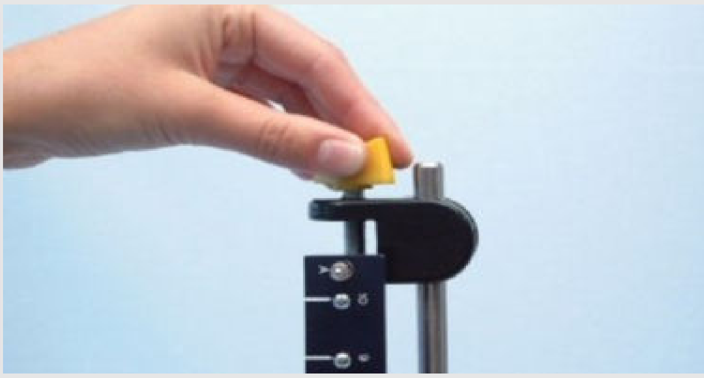
Insert the holding pin into the outermost hole of the boss head.

Attach the holding pin and the lever with the boss head to the support rod.





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Procedure (1/5)

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Reversion pendulum

- Deflect the lever and let it go.
- Measure the time t for every 10 oscillations.
- Hang the lever on the holes A, B, C and D on the left side of the lever one after the other and repeat the measurement.
- Record all resulting readings in Table 1 in the report.

Deflection of the lever

Procedure (2/5)

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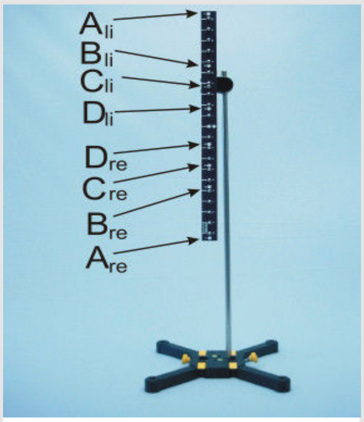

Execution of the oscillation at different suspension points

Reversion pendulums have a special property called the reduced pendulum length λ_R. The lever used has the holes A and C for this at intended places respectively.

- Measure the distance λ_R between the suspension points A_{li} (right) and C_{re} (left) and also enter this value in the table.
- Now hang the lever at point C_{re} (right) and again determine the time for 10 oscillations.
- Note the value in Table 1.

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Implementation (3/5)

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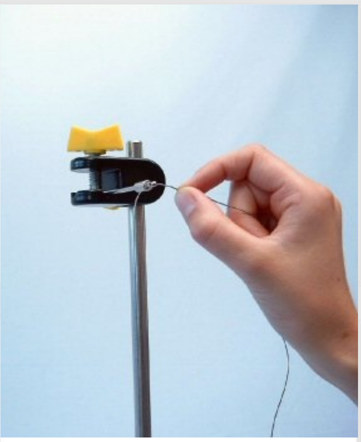


Fasten the holding pinb together with the fishing line in the boss head.

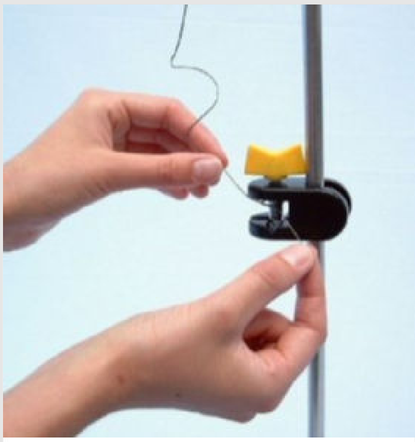
Remove the lever.

Attach the second boss head to the support rod.

Secure the holding pin with the boss head socket so that the hole at the end is horizontal.

Tie the fishing line to the hook of the weight plate and pull it through the hole in the holding pin.

Tie this free end of the fishing line to the second boss head.



Fasten the fishing line in the second boss head

Procedure (4/5)

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Fixing the mass parts

- Hang weights on the weight plate so that the total mass is 70 g.
- Adjust the height of the lower boss head so that the total length of the thread from the upper rholding pin to the middle of the weights is equal to the reduced length of the pendulum. λ_R of the reversion pendulum.
- Measure the time t for 10 oscillations and note the value in Table 2 in the report.

Deflection of the thread pendulum

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Procedure (5/5)

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Disassembly of the support base

- To disassemble the support base, press the buttons in the middle and pull both halves apart.

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Report

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Table 1

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Enter the measured values in the table. Calculate from the value t for each 10 oscillations the period of oscillation T for one period.

Also record the distance λ_R between the suspension points A_{li} (left) and C_{re} (right).

Suspension	$t\,[s]$	$T\,[s]$
A_{li}		
B_{li}		
C_{li}		
D_{li}		
C_{re}		
Thread pendulum		

$\lambda_R =$

Task 1

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Compare the oscillation durations with each other, what do you notice?

- [ ] $T(A_{li}) = T(C_{re})$
- [ ] $T(B_{li})$ is the smallest.
- [ ] $T(A_{li})$ is the greatest.
- [ ] $T(C_{li}) = T(C_{re})$
- [ ] $T(D_{li})$ is the greatest.

Check

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Task 2

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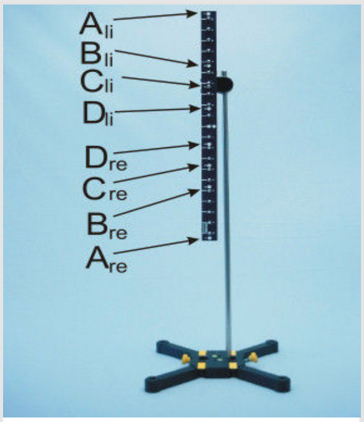

Experimental setup with different suspension points

Based on the measurement results, it can be expected that the vibration durations for the same suspension points will be X_{li} (left) and X_{re} (right) are identical in each case?

- ○ Yes, the oscillation periods are the same on the left and right at the same distance from the centre of gravity.
- ○ No, the oscillation periods differ equally on the left and right at the same distance from the centre of gravity.

Check

Task 3

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Why are the oscillation periods on the left and on the right at the same distance from the centre the same?

- ☐ The suspension points all lie on the central axis of the lever. So according to Steiner's theorem, only the distance to the body's centre of gravity is important for the oscillation.
- ☐ The oscillation periods are not the same on the left and right at the same distance from the centre.
- ☐ The lever used is regularly shaped and has an approximately homogeneous mass distribution.

Check

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Task 4

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Compare the period of oscillation of the thread pendulum with the period of oscillation of the reversion pendulum for the suspension points. A_{re}, C_{li} and C_{re}. What statement can you make about this?

- The oscillation durations have no discernible relationship to each other.
- The thread pendulum with the pendulum length $l = \lambda_R$ has a period of oscillation twice as long as the reversion pendulum when suspended at the points A_{re}, C_{li} and C_{re}.
- The thread pendulum with the pendulum length $l = \lambda_R$ has the same period of oscillation as the reversion pendulum when suspended at the points A_{re}, C_{li} and C_{re}.

Check

Task 5

PHYWE

Compare the measured reduced pendulum length λ_R by that length L of the lever.

- $\lambda_R \approx 1/2 \cdot L$
- $\lambda_R \approx 3/4 \cdot L$
- $\lambda_R \approx 2/3 \cdot L$

Check

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Task 6

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Complete the text.

If you hang a ________ at point A, there is a second point C where the ________ is just as great. The ________ between these two points is called the ________. A ________ with this pendulum length has the same period of oscillation as the reversion pendulum.

- reversion pendulum
- period of oscillation
- thread pendulum
- distance
- reduced pendulum length

Check

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