Forced oscillation and resonance

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/5fda7e86b5c96200036a66e8

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Teacher information

Application

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Experimental setup for determining the natural frequency of the spring pendulum

If an oscillating system is left to itself following an excitation, it oscillates in one its own mode. Natural modes or natural oscillations are oscillations with the natural frequency ω of the system.

If neither a further external excitation nor a damping acts, the system oscillates (idealized) infinitely, constantly with its natural frequency.

With the help of the following equation it is possible to calculate at any point in time t the deflection of the oscillation $x(t)$.

$$x(t) = x_0 \cdot cos(\omega t + \varphi_0)$$

The initial deflection x_0 the natural angular frequency ω and the phase shift $\varphi_0 =$ are used at the beginning of the oscillation.

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Other teacher information (1/2)

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Prior knowledge

The students should have already carried out some experiments on the subject of harmonic oscillation in order to have already acquired a sound knowledge of free, undamped and possibly also damped oscillation.

Scientific principle

Considering the equation of motion of the spring pendulum (spring constant k) neglecting damping, we obtain:

$$\ddot{x} + \frac{k}{m} \cdot x = 0$$

$$\Rightarrow \frac{c}{m} = \omega^2 \;\Rightarrow\; \omega = \sqrt{\frac{c}{m}}$$

Other teacher information (2/2)

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Learning objective

The students should learn that every oscillating system has a natural frequency ω which decisively determines the time course of the oscillation.

Tasks

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

1. Excite a spring pendulum by hand and observe what happens.
2. Experimentally determine the natural frequency of the spring pendulum.

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Safety instructions

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

Student Information

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Motivation

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Barre grip on the electric guitar

Stringed instruments are characterized by the fact that the different strings give off different tones. This is primarily due to the nature of the respective string (thickness, material, etc.) and the tension with which it is attached to the instrument. Secondly, the tone is varied by deliberately shortening the length of the string. The pitch is then determined by the so-called natural frequencies resulting from the frame parameters ω of the strings.

In this experiment you will look at the natural frequency of the classical spring pendulum as a simple example of an oscillating system.

Tasks

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Excite a spring pendulum by hand to oscillate and observe the effect.

Measure the natural frequency at which the spring pendulum oscillates without external input.

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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	Holding pin	03949-00	1
5	Helical spring, 3 N/m	02220-00	1
6	Set of precision weights,1g-50g	44017-01	1
7	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1

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Set-up (1/2)

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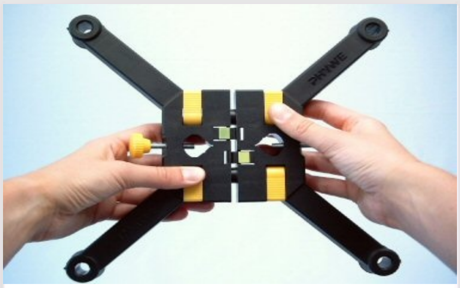
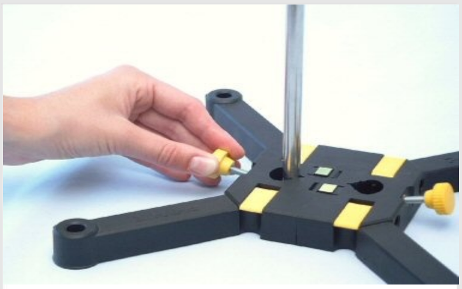
First screw the split support rod together and assemble the support base.

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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Holding pin with spring in the boss head

- Clamp the boss head to the long support rod.
- Fasten the holding pin in the boss head and hang the helical spring $(3\,N/m)$ into the hole of the holding pin.
- Attach the 50 g mass piece from the weight set to the coil spring.

Attach 50g mass piece

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Procedure (1/3)

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Deflection of the spring pendulum

- Deflect the spring pendulum downwards and let it swing uninfluenced in its natural oscillation.
- Start the stopwatch at the lower the reversal point and measure the time for 10 oscillations.
- Repeat the measurements twice and record the readings in Table 1 in the report.

Procedure (2/3)

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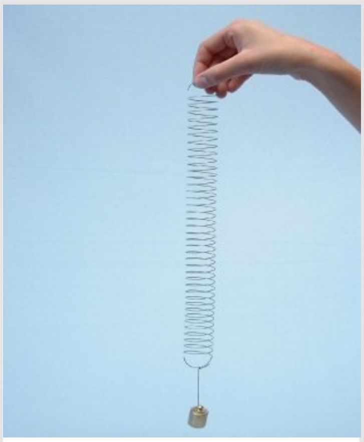

Excitation of the spring pendulum by hand

- Take the upper end of the coil spring in your hand.
- Move your hand with the spring pendulum very slowly up and down (low excitation frequency). Observe the movement of the spring pendulum and note your observations on the results page.
- Move your hand faster than before (medium excitation frequency, you want to excite with the natural frequency) and observe the spring pendulum again.
- Move your hand even faster (high excitation frequency, higher than the natural frequency) and look at the spring pendulum again.

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Procedure (3/3)

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Disassembly of the tripod 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 your readings t_{10} for the three measurements over 10 oscillations into the table.

Then calculate the mean value for the three measurements $\langle t \rangle$ and from this the period T for an oscillation.

Finally calculate the frequency of the natural oscillation f_0 from the reciprocal of the period duration:

$$f_0 = \frac{1}{T} = T^{-1} \quad \left[Hz \triangleq \frac{1}{s}\right]$$

Measurement	$t_{10}\ [s]$
1	
2	
3	

$\langle t \rangle\ [s]$	$T\ [s]$	$f_0\ [Hz]$

Task 1

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Which statements are true for your observations with low excitation frequency $(f_e < f_0)$?

- ☐ The mass piece is moving.
- ☐ The mass vibrates with the natural frequency f_0.
- ☐ The amplitude of the oscillation remains constant.
- ☐ The amplitude of the oscillation increases.
- ☐ The mass oscillates with the frequency of the exciter f_e.

Check

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Task 2

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Which statements are true for your observations with medium excitation frequency $(f_e \approx f_0)$?

- [ ] The mass oscillates with the frequency of the exciter f_e.
- [ ] The mass vibrates with the natural frequency f_0.
- [ ] The amplitude of the oscillation increases (resonance case).
- [ ] The amplitude of the oscillation remains constant.
- [ ] The mass piece is moving.

Check

Task 3

PHYWE

Which statements are true for your observations with high excitation frequency $(f_e > f_0)$?

- [ ] The mass oscillates with the frequency of the exciter f_e.
- [ ] The mass vibrates with the natural frequency f_0.
- [ ] The amplitude of the oscillation remains constant.
- [ ] The mass piece moves little.
- [ ] The amplitude of the oscillation increases.

Check

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Task 4

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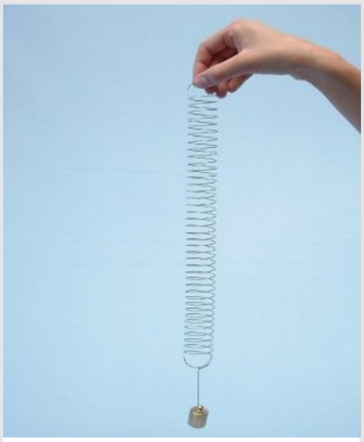

Excitation of the spring pendulum by hand

How does the amplitude or the frequency of the spring pendulum behave at

1. Low excitation frequency: ______
2. Medium excitation frequency: ______
3. High excitation frequency: ______

- The pendulum follows the exciter (amplitude & frequency).
- The pendulum swings at maximum amplitude.
- The pendulum is almost at rest.

Check

Task 5

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Which parameters influence the natural frequency ω

- [ ] The spring constant k.
- [ ] The excitation frequency f_e (hand gesture).
- [ ] The ambient air pressure p_0.
- [ ] The attached mass m.

Check

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Slide	Score / Total
Slide 17: Observation at low excitation frequency	0/3
Slide 18: Observation at medium excitation frequency	0/4
Slide 19: Observation at high excitation frequency	0/3
Slide 20: Amplitude behavior	0/3
Slide 21: Parameters of the natural frequency	0/2

Total 0 / 15

Solutions Repeat Export text

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