Forced Vibration and resonance (Item No.: P6201200)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 14-16	Mechanics	Oscillations	Forced Vibration and Resonanz

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	20 Minutes	2 Students

Additional Requirements:

- Tablet PC with DigiCart App

Experiment Variations:

Keywords:

Forced oscillation, Resonance

Information for teachers

Introduction

Overview experimental setup.

Educational objective
In this experiment the students learn something about the behaviour of forced oscillations. The dependence of the resonance frequency on the mass is investigated.

Task
1) Investigate qualitatively the amplitude behaviour as a function of the excitation frequency.

2) Investigate quantitatively the dependence of the resonance frequency on the mass.

Prior knowledge
This experiment requires the understanding of harmonic oscillations.

Principle
Oscillations

Oscillations are repeated temporal fluctuations of state variables of a system. Vibrations can be characterized by the amplitude

A and the frequency f. The amplitude describes the extent of the oscillation from a defined equilibrium position. The frequency indicates how many oscillations the system carries out in one second. The frequency depends on the period time T of the oscillation via the relation

$$f = \frac{1}{T}.$$

Forced oscillation

The forced oscillation imposes an external frequency on the system. An example is a mechanical mass-spring-system. If one sets up the differential equation for this and solves it, one receives oscillations. In the most general case these are damped. The amplitude of the oscillation will depend on the external imposed frequency. For a certain value, the eigenfrequency of the system, the amplitude becomes maximal. This case is called resonance. Mathematically it follows for the natural frequency f_R that

$$f_R^2 \sim \frac{1}{m}.$$

The spring constant D occurs as a proportionality factor.

Notes concerning the set-up and execution of the experiment
It is important to start with four additional weights on the DigiCart, as the oscillation is too unstable if the weight is too low.

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart white		1
2	1.2 m track		1
3	Height adjustable holder		1
4	DigiCartAPP		1
5	Spring set (5 springs)		1
6	Weights 50g		4
7	Plastic screws		4
8	Vibration motor		1
9	Scale		1

Safety information

For this experiment, the general instructions for safe experimentation in science teaching apply.

Introduction

Application and task

Application
Forced oscillations are numerous in nature and technology. For example, we owe the fact that we are able to hear to the forced oscillation of the eardrum excited by sound waves.

In this experiment you will learn about the behavior of forced oscillations. The dependence of the resonance frequency on the mass is investigated.

Task
1) Investigate qualitatively the amplitude behaviour as a function of the excitation frequency.

2) Investigate quantitatively the dependence of the resonant frequency on the mass.

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart white		1
2	1.2 m track		1
3	Height adjustable holder		1
4	DigiCartAPP		1
5	Spring set (5 springs)		1
6	Weights 50g		4
7	Plastic screws		4
8	Vibration motor		1
9	Scale		1

Set-up and procedure

Set-up

Figure 1: Overview of experimental setup.

- Fix the vibration motor to the side of the height-adjustable end of the track so that the motor shaft points down towards the track (see Figure 1).
- Bring the end of the track to the highest point using the height-adjustable holder so that the track is at its maximum incline.
- Mount all four additional weights of 50 grams each on the DigiCart using the plastic screws.
- Use the scale to determine the weight of the DigiCart.
- Place the DigiCart on the inclined track and connect it with one of the five springs to the vibration motor.

Note: The spring is fixed to the DigiCart in the eyelet above the force sensor.

- Start the DigiCart App.
- Select experiment 12 from the overview. The measurement window opens.
- Connect the DigiCart to the app (see Figure 2). Two steps are required. First, press the ON switch on the DigiCart for at least 3 seconds. Then open the connection window in the app via the bluetooth symbol (1.). The DigiCart should now be displayed there. If not, you can update the list by clicking on scan (2.). Now, one taps the DigiCart from the list once and establishes the connection via the connect button (3.). You can now hide the window again by pressing the close button (4.).

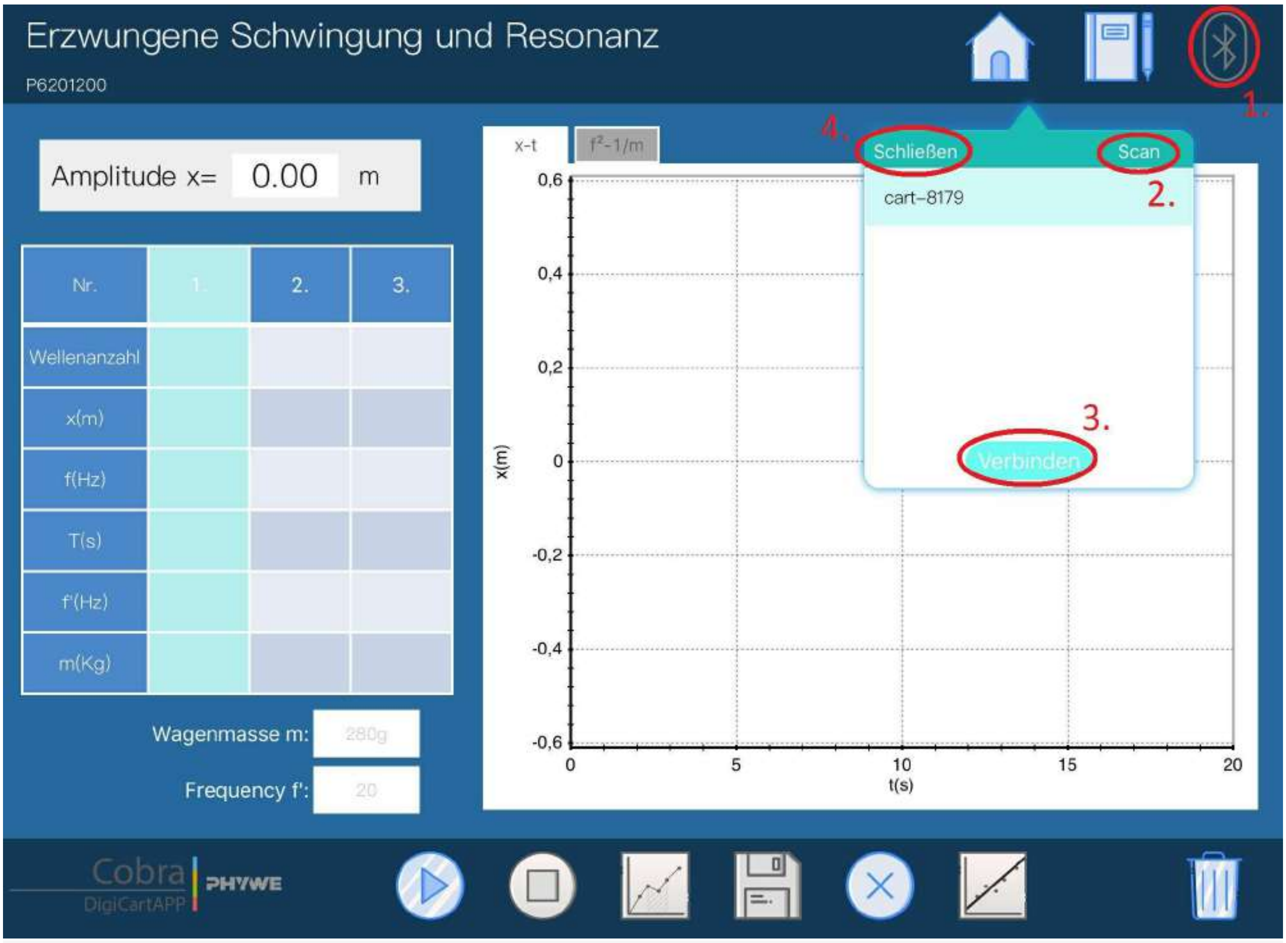

Figure 2: Connecting to the DigiCart.

Procedure

Part 1

- Figure 3 shows the steps for the measurement process.
- Start the measurement by clicking on start measurement (1.).
- Switch on the vibration motor (ON/OFF switch) and slowly but continuously increase the frequency of the motor at the rotary knob. Observe the recorded vibration.
- The amplitude of the oscillation will slowly increase to a maximum value and then decrease again.
- Stop the measurement by clicking on stop measurement (2.) as soon as the amplitude has fallen below a visible value.
- You should get a curve as in Figure 3.

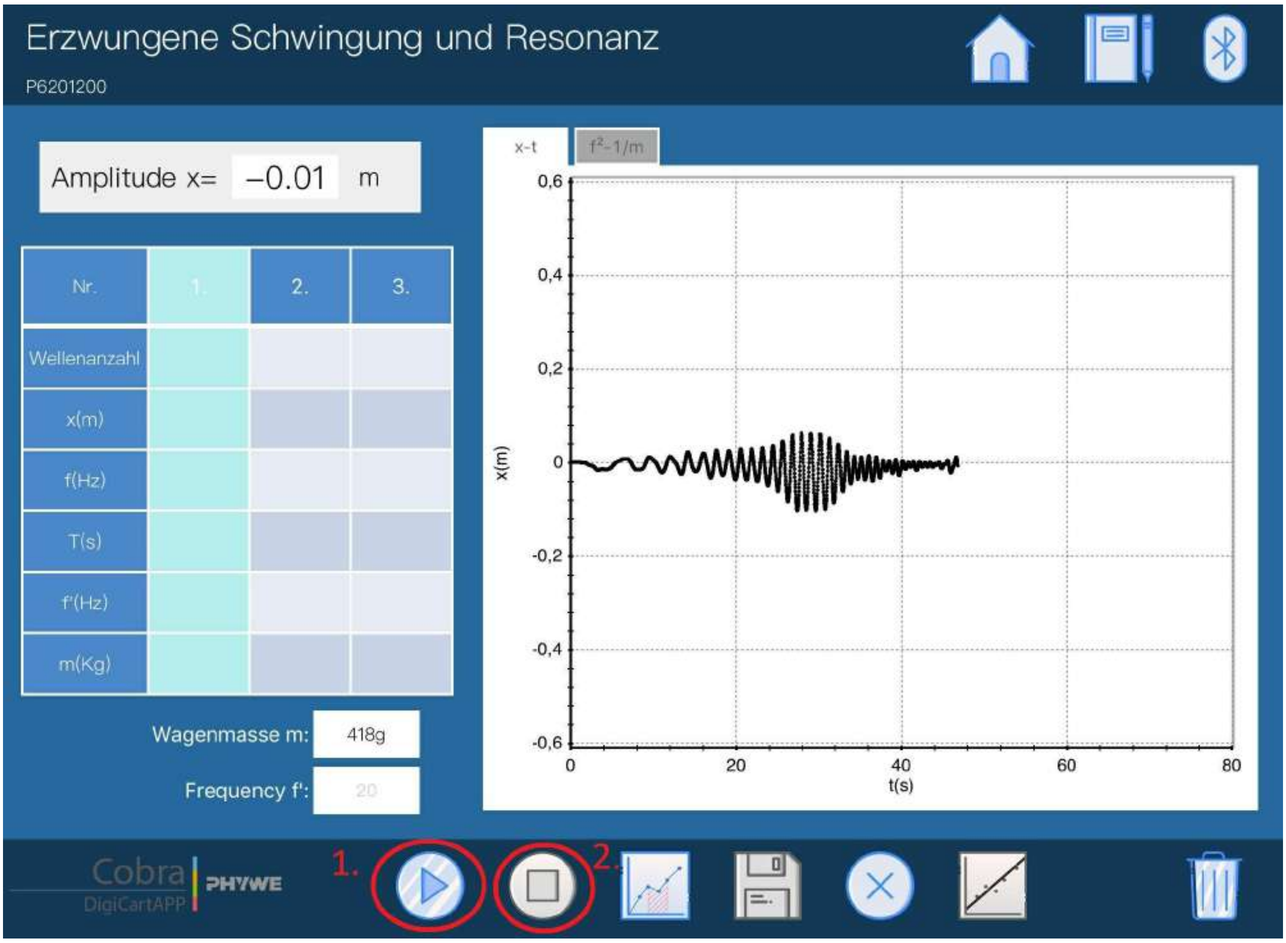

Figure 3: Measurement procedure - Part 1

Part 2

- Figure 4 shows the steps for the measurement process.
- The amplitude display (1.) shows the current oscillation amplitude.
- Enter the measured mass of the DigiCart in the car mass field (2.).
- Enter the value 1 in the frequency field (3.).
- Start the measurement by clicking on start measurement (4.).
- Switch on the vibration motor (ON/OFF switch) and modulate the frequency with the rotary knob until you have hit the resonance frequency (maximum amplitude of the DigiCart).

Remark: Take your time for the last step. It is important that you find the resonance frequency.

- End the measurement by clicking on end measurement (5.).
- Start a new measurement by clicking on start measurement (4.) at the set resonance frequency and record at least 10 oscillation periods.
- End the measurement by clicking on stop measurement (5.).
- By clicking on select measuring range (6.), select a range in the oscillation diagram that includes at least 10 oscillation periods. The selection is made by sweeping the interval with the finger. Then click on the save button (7.).
- Remove an extra 50 grams of weight from the DigiCart and repeat the last 8 steps.
- Then remove another 50 grams of additional weight from the DigiCart and repeat the 8 steps again.
- To delete a column from the table, touch it and then click the delete button (8.). A new measurement can fill the column with new values.
- Click on the tab " $f^2 - 1/m$ " above the diagram (9.) after three measurements have been taken.

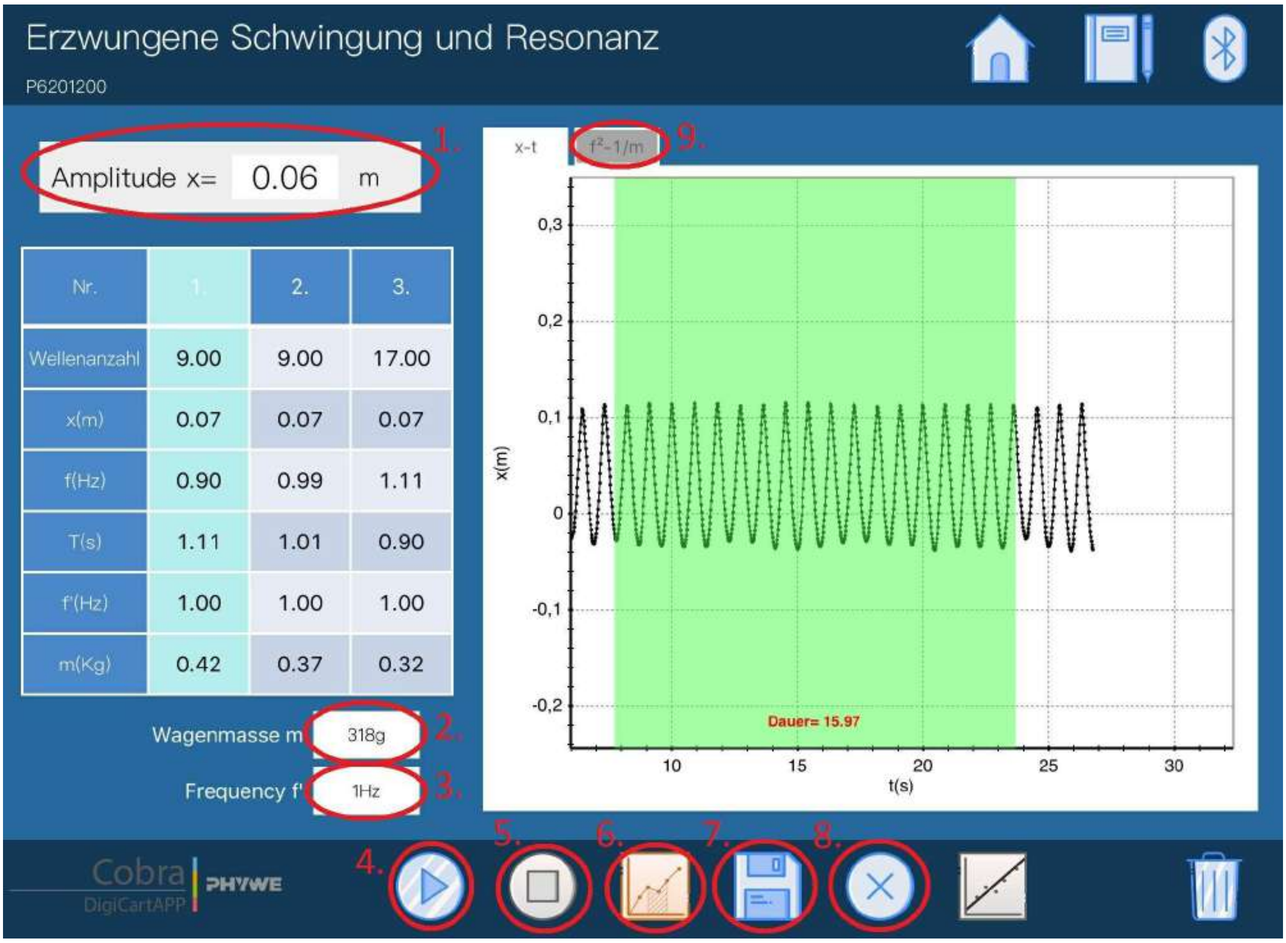

Figure 4: Measurement procedure - Part 2

Evaluation

- Figure 5 shows the steps for the evaluation.
- In the diagram, the square of the measured resonance frequency is plotted against the inverse of the mass.
- These values have already been calculated for each measurement and are shown in the diagram.
- Click on the straight line button (1.) and let a straight line pass through the points.

Remark: Repeat part 2 and evaluation also for springs of other strength.

Part 1

Figure 3 shows the amplitude curve over time with modulation of the excitation frequency. As you can see, the amplitude first increases to a maximum value and then decreases again. The maximum value occurs exactly at the resonant frequency at which the system oscillates the most.

Part 2

The points in the diagram in Figure 5 lie almost perfectly on the drawn straight line. This confirms the mathematical connection that the square of the resonance frequency is proportional to the inverse of the mass.

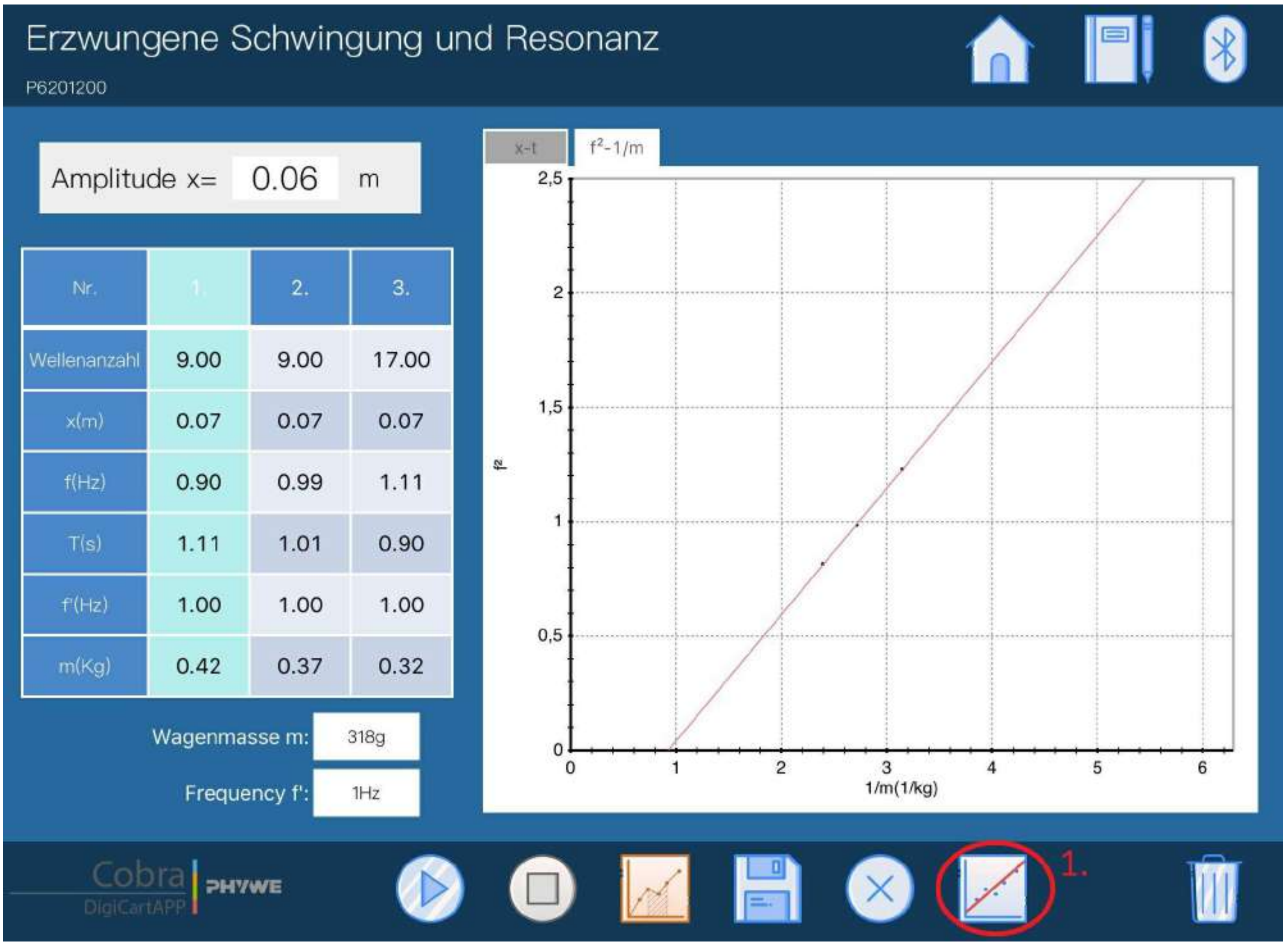

Figure 5: Evaluation procedure.

Forced Vibration and resonance

Results - Evaluation 1 (1 point)

What causes the resonance?

Score is granted based on the occurrence of the following keywords:

- In the case of resonance, energy is supplied to the system at exactly the right moment, so that the amplitude of the oscillation continues to increase.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 2 (1 point)

Which everyday example can you think of where resonance is acting?

Score is granted based on the occurrence of the following keywords:

- Swinging. By shifting your body weight, you provide the pendulum with energy at the right moment so that you can swing higher and higher.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 3 (1 point)

Which size influences the slope of the straight line in the $f^2 - 1/m$ diagram?

Score is granted based on the occurrence of the following keywords:

- The slope depends on the spring used. The spring constant is a proportionality factor.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

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Results - Evaluation 4 (1 point)

What is the relationship between the oscillation period and the frequency?

Score is granted based on the occurrence of the following keywords:

- f=1/T.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE