Driven and Damped Pendulum

Objectives:

At the end of the activity the student should be able:

1. Identify the effects of driven and damped oscillation
2. Find the frequency in which the pendulum system will experience resonance for a specific length, *l*.
3. Differentiate the period of the pendulum swinging in air than the period of pendulum swinging under water.

Introduction:

An oscillation is a motion that repeats itself over and over. Motion that repeats itself at regular intervals is called periodic motion. You are most likely familiar with several examples of periodic motion, such as the oscillations of a block attached to a spring, a child playing on a swing, the swinging pendulum of a grandfather clock, a car bouncing up and down on its shock absorber, sound vibrations produced by a musical instrument, etc.

In this experiment, a simple pendulum is attached on a speaker connected in an amplifier. A function generator was used for the input frequency. The motion detector is then placed 0.50m away from the equilibrium position of the pendulum and is connected to the Lab Quest. In this manner, the Lab Quest allows us to measure its displacement as the pendulum swings.

Theory:

The usual pendulum system consists of a bob and being suspended by a massless string, this system is free to oscillate back and forth toward the equilibrium position.

For a simple harmonic motion $\theta < 20°$, the time that will complete one cycle is what we call period, given by:

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{l}{g}} \qquad (1)$$

where *l* is the length of the string and *g* is the acceleration due to gravity.

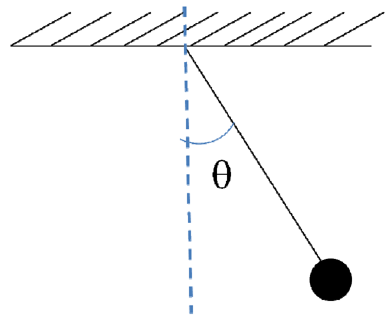


Figure 1: Simple Pendulum

In reality, the amplitude of oscillation decreases in time. This decrease in amplitude is called damping, which is caused by the dissipative forces present in a system. The corresponding motion for such system is called damped oscillations.

External force is usually applied to compensate the decrease in amplitude of oscillation. A damped oscillation is said to be driven if an external time dependent force is present in the system. If we consider a sinusoidal external force characterized by a frequency *ω,* another phenomenon can take place. When the frequency of this driving force matches the natural frequency of the system given by

$$\omega_0 = 2\pi f_0 = \sqrt{\frac{g}{l}} \qquad (2)$$

the system will experience resonance.

At resonance, the system will have greater amplitude compared to other frequencies.

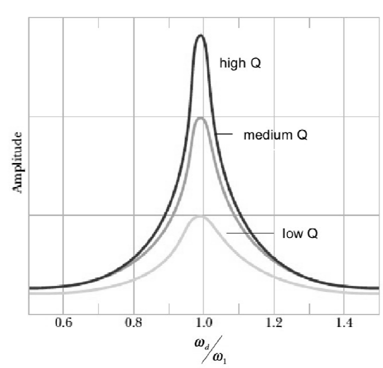


Figure 2: Resonance Graph
(http://umdberg.pbworks.com/w/page/52183487/Driven%20oscillators%3A%20resonance)

Reference:

- Young and Freedman, University Physics 11th Ed., Pearson Education South Asia Pte Ltd. © 2004.

Materials:

Function generator, amplifier, speaker, motion detector, lab quest, container, stopwatch, meter stick, nylon string and a massive bob.

Procedure:

A. Resonance

1. Tie the pendulum (nylon string of 0.64m tied with mass) on the metal rod attached on the speaker.

2. Connect the speaker at the back of the amplifier. Insert the wires of the speaker on the "main speaker".

3. Connect the function generator to the female jack of the amplifier located at the back.

4. Connect the Lab Quest into the motion detector (Follow the instructions in Appendix A illustrating how to setup the Lab Quest).

5. Setup the motion detector 0.50m away from the equilibrium position of the pendulum. The materials should be as shown in the figure.

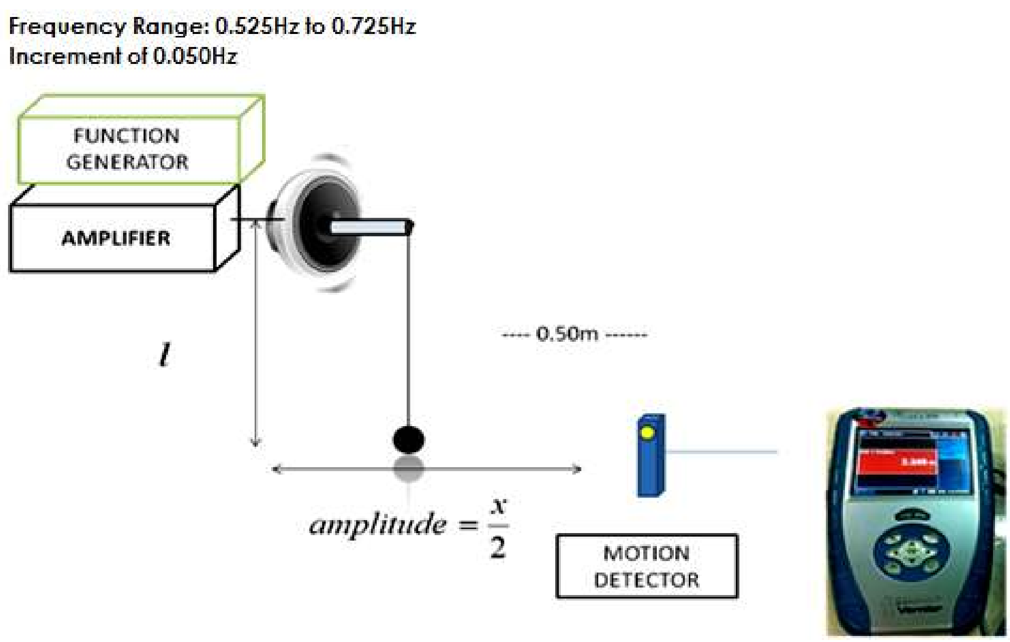


Figure 3: Experimental Set-Up for Part A

6. Set the input frequency to 0.525Hz. Measure the pendulum's displacement when it reaches its maximum.

7. Repeat step 6 but this time put an increment of 0.050Hz. At each increment, the displacement should be measured when the pendulum is at rest. Do this until you reach 0.725Hz.

B. Underwater Pendulum

1. Modify the experimental set-up as follows:

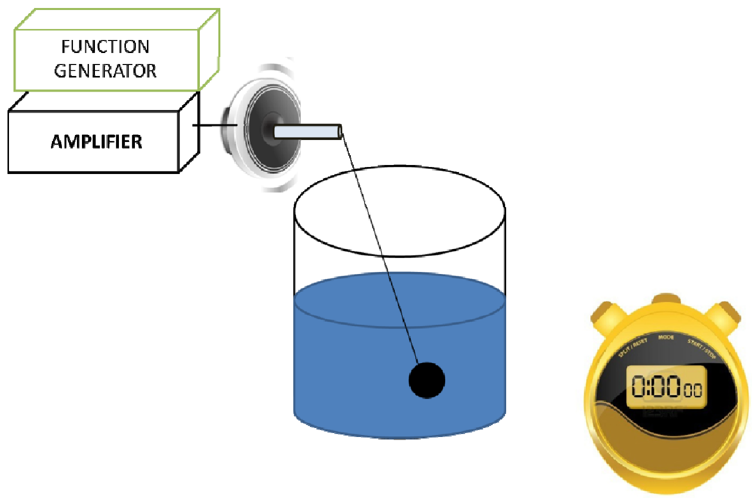
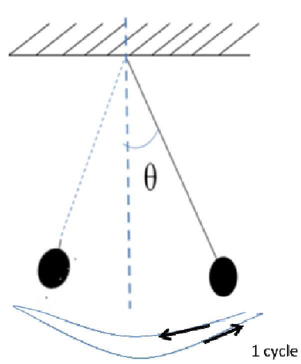


Figure 4: Experimental Set-Up for Part B

Make sure to use a circular container to avoid additional uncertainty in the motion of the water.

2. Using the resonance frequency from part A, record the period of oscillation and make at least three trials.

Figure 5: Pendulum cycle



3. Remove the container with water, this time record the period of oscillation as the pendulum swings in air.

4. Compare your results. Observe proper significant figures and absolute and relative uncertainty.

Appendix A: Setting up the Lab Quest

1. Connect the motion detector into DIG1/DIG2 port of the Vernier Lab Quest ®.

2. In the home screen, click the "sensor" button and find the port where the motion detector is detected.

3. If the Lab Quest is connected properly, continuous clicks will be heard from the motion detector.

4. Press the play button to collect data and save it by exporting your file using a flash drive.

Name:	Date:	Score:
Group Members:		Section:

Worksheet:

Driven and Damped Pendulum

Data Summary:

I. Identifying the resonance frequency of a pendulum. Let *l* = 0.64 m

Data Table 1: *Frequency, Amplitude, Amplitude^2*

Frequency (Hz)	Amplitude (m)	Amplitude^2 (m^2)

Solution:

- What frequency has the highest amplitude?

Graph 1: *Position vs Time (Frequency: _____)*

Graph 2: *Position vs Time (Frequency: _____)*

Graph 3: *Position vs Time (Frequency: _____)*

Graph 4: *Position vs Time (Frequency: _____)*

Graph 5: *Position vs Time (Frequency: _____)*

- Compute for the theoretical frequency.

Graph 6: *Resonance (amplitude^2 vs. frequency)*

II. Identifying the period of pendulum swinging underwater.

Data Table 1: *Period Underwater*

Frequency (Hz)	Length (m)	Experimental Period (underwater)		
		Trial 1	Trial 2	Trial 3

Data Table 2: *Period in air*

Frequency (Hz)	Length (m)	Experimental Period (air)		
		Trial 1	Trial 2	Trial 3

Data Table 3: *Average Period and Percentage error*

Average Period (underwater)	Average Period (air)	%error

- What makes the period underwater longer than in air?

- Calculate the theoretical period and compare it to your results (in air).