# Acrylic Pendulum Wave

P4-1755

INSTRUCTIONAL GUIDE

## Contents

- (9x) 7/8" (22 mm) steel balls with holes
- Pendula string
- Brass eyelets
- 3-piece frame
- Initiator stick

Recommended for activities:
- Slotted Mass Set (P1-1073)
- Digital Stopwatch (52-3200)
- Meter Stick (P1-7072)
- Extra masses

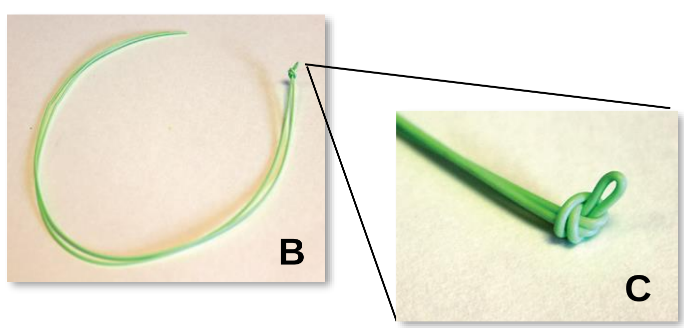
## Introduction

Nine pendula of different lengths, from a simultaneous start, display a captivating wave-like parade that shows all the possible phase relationships before returning to unison to start all over again. When set in motion, the pendulum has a maximum position and therefore maximum potential energy at two points at either end of its arc. The maximum velocity is at the equilibrium point and therefore that is where the kinetic energy is at its maximum. The pendula make slightly less to slightly more than one swing per second. Assembly of the device is intended to be fun and part of the learning experience.

## Assembly

1. When setting up the Pendulum Wave Demonstration for the first time, the frame of the pendulum needs to be put together. Interlock the notches on the ends to form the Wave Demonstration structure **(A)**. The pieces fit tightly, but they can easily be taken apart for storage.


2. Take a piece of fly line and fold it in half, then tie a knot in the end where the line was folded **(B-C)**. This forms two strings to mount the pendulum to the frame with. Repeat this process with all 9 pieces.





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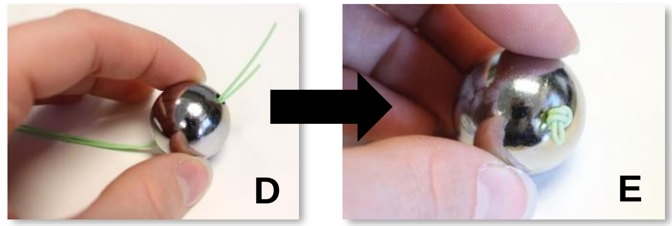
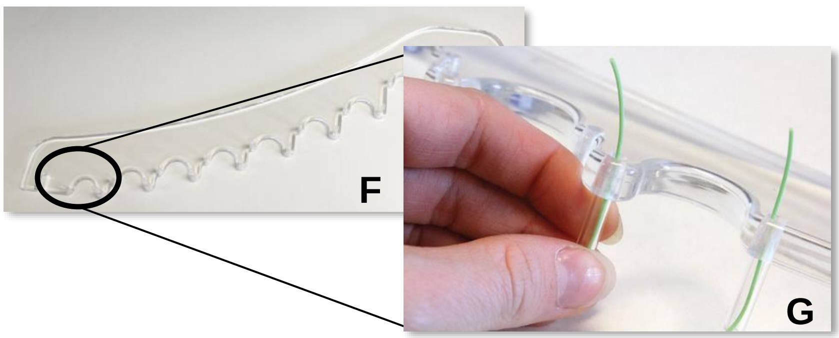
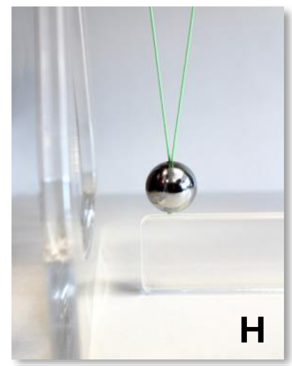
3. Thread both ends of a knotted fly line through one of the drilled steel balls **(D)**. Pull the ball all the way down to the knotted end so that they fit tightly against each other **(E)**. Repeat threading the fly line through the remaining steel balls.



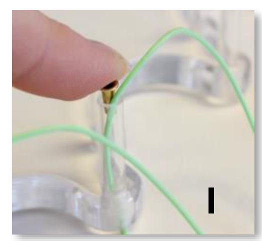

4. Prop the initiator stick onto its side and place it underneath the frame. Start threading the fly lines of a pendulum to the first parallel set of tubes on the frame, as indicated by the circle in image **(F)**. Pass each end of the line through a separate tube so that some of the fly line is extending past the acrylic frame **(G)**. Adjust the length of the line so that the bottom of the ball aligns with the top of the initiator stick **(H)**.




Note: *After the Acrylic Pendulum Wave is completely assembled, the extra lines can be taped to the frame, or cut (do not cut lines until assembly and adjustments are finished).*

5. To keep the pendula in place, push the smaller end of a small brass eyelet into each tube opening, this will secure the fly line. You may need to adjust the pendula later, so there is no need to push the eyelet in all the way at this point, just insert it enough to securely hold the line **(I)**.




6. Repeat Step 4 and 5 with the remaining pendula, mounting them from left to right on the frame, aligning them to the initiator stick underneath. After the 9 pendula are adjusted, the steel balls should form a straight line with the same distance from the bottom of each ball to the table.

7. Use the measurements to the right to adjust the pendula to the correct lengths as needed. Measurements can be made in number of swings per 20 seconds or by the distance (in cm) between the middle of each ball and the bottom of the tube it is attached to.

| Swings in 20 s | Length (cm) |
|---|---|
| 24 | 17.2 |
| 23 | 18.8 |
| 22 | 20.5 |
| 21 | 22.8 |
| 20 | 24.8 |
| 19 | 27.4 |
| 18 | 30.6 |
| 17 | 34.6 |
| 16 | 38.8 |

8. To test the Wave Demonstration, hold the initiator stick against all steel balls and push them backward simultaneously. Then, quickly remove the stick and watch the Acrylic Pendulum Wave swing through its phases. It might take several rounds of adjustments to perform perfectly.

9. After all adjustments have been made and the Pendulum Wave Demonstration is performing as desired, the extra fly line can be taped or cut, and the eyelets can be pushed in completely.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## Activities

1. Review that frequency is simply how often something happens during a period of time. Introduce to the students one piece of string approximately 1 meter long. Cut the string unevenly to produce a short piece and a long piece (65 cm and 35 cm). Attach a washer or nut to each piece of string. Have one student hold each string at the same level in front of the class. Ask students what will happen to the frequency of each string. How will the frequencies be similar or different? Which string will have a higher frequency than the other and why? Conduct the experiment with the small and large string starting the string parallel to the floor and releasing the washer at the same time. Count the frequency cycle of each washer.
2. Introduce the pendulum wave. Give students time to observe the pendulum wave. What do they observe? Elicit whole group discussion on what they think will occur. After discussion, using the bar included, start the pendulum wave by starting all pendulums at the same time. Allow students to enjoy the show or come up and start the pendulum wave themselves.
3. Assign lab groups different variables to collect and have them tabulate and graph their data. Then have them present their data and explain what patterns in their findings lead them to their conclusion. Have the other lab groups chime in to evaluate the conclusions. Do they agree? The variables they can collect are below:
    a. Collect data for the time it takes for each pendulum to complete one period.
    b. Collect data for the time to complete one period when amplitude is increased. Use a protractor to achieve consistent release points.
    c. Collect data on period times and different masses. Be sure to keep the pendula the same length.
4. Use a camera to capture images of the patterns from above and lengthwise. Identify when all the pendulums are in phase, when all the even ones are in phase and the odd ones are too. Identify the wavelength and amplitude of each pendulum. Identify when the pattern demonstrates constructive and destructive interference.

## NGS Standards

**Students who demonstrate understanding can:**
**4-PS4-1** Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

**MS-PS4-1** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

**HS-PS2-1** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

**AP Physics**
**3.B.3.1** The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.

**3.B.3.2** The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.

**3.B.3.3** The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.

**3.B.3.4** The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.


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## Related Products

Pendulum Lab (P4-1700) Experiment with different weights, lengths, and amplitudes to find out which affects the period. Includes whiteboard for recording experiment parameters.

Spring Wave (P7-7220) Use this highly visible Spring Wave to observe phase reversal at the fixed end of wave pulses and to test fundamental and multiple vibrations. Experiment with determining the speed of propagation of transverse and longitudinal waves. Expands 20in to 12ft.

Sound Wave Interference Kit (P7-7600) Now you can get a complete economical solution for demonstrating wave interference on a classroom size scale. Kit includes signal generator and powered speakers, everything you need for this great demonstration.


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