# Standing Wave Generator

Electron Configuration

## Introduction

Teachers can demonstrate a standing wave by using a centrifuge device with a simple attachment. The discussion of wavelength and amplitude will become much more concrete as students see these principles for themselves!

## Concepts

- Properties of waves
- Wavelength
- Nodes
- Antinodes
- Amplitude
- Frequency

## Materials

Battery, D size
Bracken's Demonstration Spinner
Candle or burner
Cotton cord
Paper clip or dissection needle
PVC elbow
PVC pipe, long
PVC pipe, short, with cup hook
Ring stand
Soda bottle cap
Strobe light (optional)
Swivel, hole and latch
Swivel, two holes

## *Safety Precautions*

*Make sure hooks are firmly connected before operating the centrifuge. Do not touch the motor axle while rotor is spinning. Remove the battery from Bracken's Demonstration Spinner when not in use and during storage.*

## Procedure

1. Thread one end of the cotton cord through the 2-hole swivel and tie.
2. Melt a hole in the center of the flat surface of the cap (see Figure 1) using a heated straightened paper clip or dissection needle. (A candle or burner may be used to heat the paper clip.) The motor axle of the centrifuge device should fit snugly through this hole.

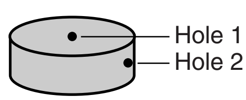


**Figure 1.** Cap

3. Melt a second hole on the side of the bottle cap.
4. Place the cap, flat side down, on the axle of Bracken's Demonstration Spinner through the center hole.
5. Tie the loose end of the cord through the hole of the swivel with the hole and latch. Clip the latch of the swivel to the hole on the side of the bottle cap.
6. Attach the PVC elbow to the two PVC pieces as shown in Figure 2.
7. Place the 2-hole swivel onto the cup hook (see Figure 2).
8. Slide the long PVC piece over the rod of the ring stand.
9. Turn on the motor and observe the wave pattern in the cotton cord.
10. Vary the number of nodes by changing the tension on the rope. This is easily done by holding and raising the PVC

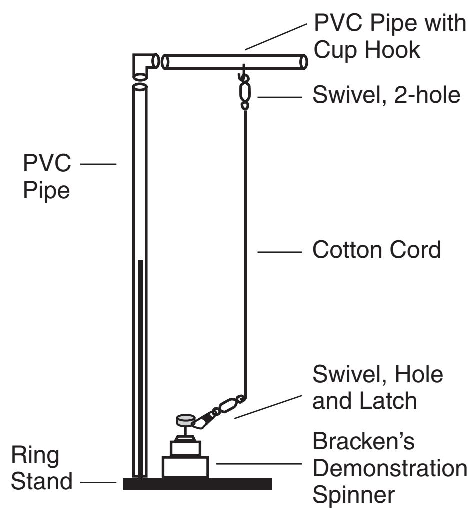


**Figure 2.** Setup

pipe assembly to tighten the rope.

## Tips

- Bracken's Demonstration Spinner, Flinn Catalog No. AP6202, is required and sold separately.
- The number of nodes can be counted and the wavelength, amplitude, etc. for each wave pattern can be measured.
- A strobe light can be used with this demonstration to "fool" our eyes. If the strobe light is properly adjusted, the spinning rope will appear motionless! This should be done in a dark room. Be advised that the use of strobe lights can trigger epileptic seizures in some people. Check to make sure that none of your students have epilepsy before using a strobe light.

## Discussion

All traveling waves follow the *principle of superposition*. That is, when two or more waves meet at the same location the waves overlap with each other and add together to instantaneously create a new wave form. However, the original wave patterns are not lost. Instead, they travel through each other, interact with superposition, and then emerge with the same original shape (see Figure 3).

The superposition of two or more waves creates two types of interference—constructive interference and destructive interference. *Constructive interference* occurs when two or more waves combine at the same location and instantaneously produce a wave form with a larger amplitude than any of the original waves. *Destructive interference* occurs when two or more waves combine at a given location to instantaneously produce a wave with a lower amplitude than any of the original waves. When two continuous waves traveling in opposite directions with the same frequency interact with each other, an interesting wave form can be created. If the waves are the correct frequency, a *standing wave* is produced (see Figure 4). A standing wave form is the result of constructive and destructive interference of waves that interact in such a way to make the peaks (antinodes) and valleys (nodes) of the wave remain fixed in space.

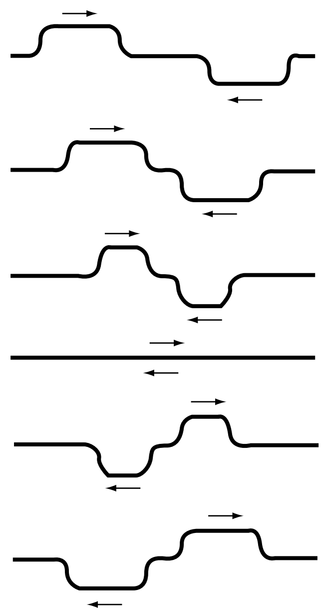

**Figure 3.** Principles of Superposition

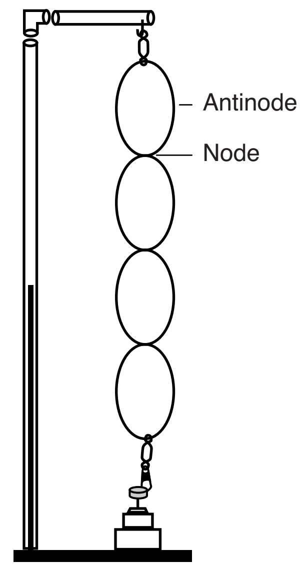


**Figure 4.** Standing Wave

For a string fixed (tied) at both ends, there are only certain frequencies that will create standing waveforms in the string. The continuous waves that interfere and create the standing wave form are the initially transmitted wave and the wave that is reflected at the fixed end and sent back toward the source. Both of these waves will have the same frequency (the reflected wave's amplitude may be slightly lower than the original waveform). Only specific frequencies will create a standing wave pattern in the string. The specific frequencies are called *harmonics*. The properties of the string (or any medium that is fixed at both ends) that determine which frequencies are "harmonic" are the length of the string and the velocity at which the waves can travel through the string according to Equation 1. The first harmonic (when n = 1) is also known as the *fundamental frequency*.

$$f_n = \frac{n\,v}{2\,L} \qquad \textit{Equation 1}$$

$f_n$ = frequency of the nth harmonic
n = harmonic number (i.e., 1, 2, 3, …)
v = velocity of the waveform traveling through the string
L = length of the string

The velocity at which a wave can travel through a string depends on the tension in the string and the mass per unit length of the string (Equation 2).

$$v = T/\mu \qquad \textit{Equation 2}$$

T = tension in the string
μ = mass of the string per unit length

Combining Equation 1 and Equation 2 shows that the higher the tension in the string, the higher the fundamental frequency (and all the other harmonic frequencies) will be. These harmonic variations are shown when the Standing Wave Generator's string is pulled tight or loosened. When the string is loose, the frequency (revolutions per minute) of the spinning centrifuge device may be high enough to produce a 3rd or 4th harmonic (three or four antinodes) in the string. As the string is pulled tighter, the wave pattern decreases to a 1st or 2nd harmonic (one or two antinodes) because the higher string tension requires a higher fundamental frequency to produce a standing wave. There are also intermediate tensions in which no standing wave-forms are created because the frequency of the spinning centrifuge (constant) is not a harmonic frequency for the string at that particular tension.

Other wave properties like frequency, wavelength, nodes and antinodes can also be discussed using this wave generator. Please refer to your physics/physical science textbook for more information on these principles.

## Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

***Unifying Concepts and Processes: Grades K–12***
Systems, order, and organization
Evidence, models, and explanation
***Content Standards: Grades 5–8***
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy
***Content Standards: Grades 9–12***
Content Standard B: Physical Science, structure and properties of matter, interactions of energy and matter

## Acknowledgment

Flinn Scientific would like to thank Jeff Bracken, chemistry teacher at Westerville North High School in Westerville, Ohio for sharing this original idea. Jeff would like to thank his student lab assistant, Ben Swanger, for his valuable assistance in creating this demonstration.

## Reference

Tipler, Paul A. *Physics for Scientists and Engineers*, 3rd Ed., Vol. 1; Worth Publishers: New York, 1990; pp 414–424.

## Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Standing Wave Generator* activity, presented by Jeff Bracken, is available in *Electron Configuration*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

## Materials for *Standing Wave Generator* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Standing Wave Generator* available from Flinn Scientific. Materials may also be purchased separately.

| Catalog No. | Description |
|---|---|
| AP6161 | Standing Wave Generator |
| AP6202 | Bracken's Demonstration Spinner |
| AP1425 | Battery, Replacement, D size |
| AP5720 | Stroboscope |

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.