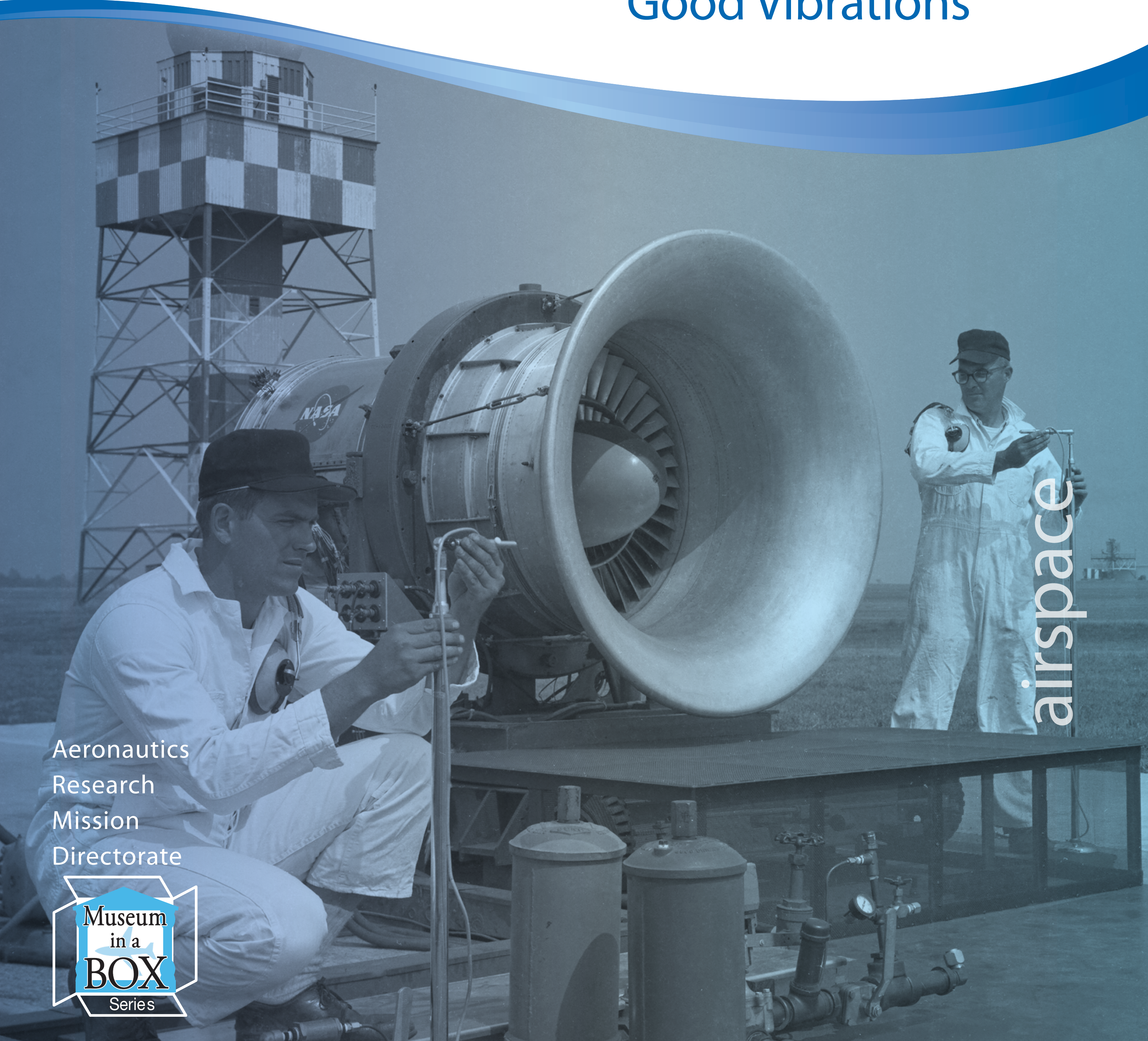
National Aeronautics and Space Administration

GRADES **9-12**

Good Vibrations



airspace

Aeronautics
Research
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Museum in a BOX Series

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Good Vibrations

Lesson Overview

Noise from aircraft is an increasing problem in our environment. Contributing factors include an increase in air traffic, demand for land in cities which has pushed development close to airports and larger aircraft which require more powerful engines. Science, Technology, Engineering, and Mathematics (STEM) will help solve this problem. Many groups are working to create solutions. The following three hands-on activities will help students better understand several basic principles of sound:

Tuning Forks: Students will engage in a series of demonstrations that illustrate the concept of vibrations, pitch, frequency, and beats.

Thunder Drum: Students will add a simple spring to the design of a thunder drum and hear very unusual sounds.

Resonator: Students will directly observe resonance in a pair of demonstrations using a series of wooden dowels to illustrate the concepts of natural frequency and resonance.

Student worksheets are provided.

Objectives

Students will learn about transfer of energy, motions and forces, and interactions of energy and matter as they learn about the following concepts:

1. Several principles of sound.
2. Noise from aircraft is a growing problem that NASA along with many others are working to reduce the amount of.
3. All sounds are caused by vibrations.
4. Vibrations can be sensed in several ways (hearing, seeing and touching).
5. Pitch is related to the speed or rate of vibration.
6. Resonance.
7. Natural frequency of an object.

Materials:

In the Box

1 stick of modeling clay

2 wood dowel rods, 1/8″ diameter, 18″ long

1 wood dowel rod, 3/16″ diameter, 36″ long

1 wood dowel rod, 3/16″ diameter, 24″ long

1 wood dowel rod, 3/16″ diameter, 30″ long

2 wood dowel rods, 3/16″ diameter, 18″ long

Sandpaper

7 Sponge balls

Wood base, predrilled

Safety glasses

Provided by User

Table

Phillips-head screwdriver or nail

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Time Requirements: 45 minutes

Background

As scientists and engineers work to reduce noise pollution from aircraft, a thorough understanding of the physics of sound is necessary. Sound is one of the most important ways we have of sensing our surroundings and of communicating with others. Sound itself is a sensation created in the human brain in response to sensory inputs from the inner ear. However, not all sounds are desirable or beneficial.

All sounds are produced by vibrating objects. One of the reasons that there are so many different sounds is that there is an endless variety of materials that can vibrate and produce them. When you talk or sing, two ligaments that are hidden in your larynx vibrate. They are called your vocal cords, or vocal folds. Each person has a unique set of vocal cords and a uniquely designed larynx which gives rise to the individual character of a person's voice.

Following are some properties of sound waves:

- Frequency and pitch depend on the length of an object that is vibrating; a short string will vibrate faster producing a higher frequency (or pitch) than a long string.
- Multiple sound waves can reinforce or interfere with each other.
- Sound insulation is designed to absorb sound waves. Many of the same materials used in temperature insulation can be used to reduce sound.
- Sound can be reflected (bounced off) or refracted (bent).
- Sound levels decrease rapidly as the distance from the point of origin to the receiver increases; if the distance from the source is doubled, then the intensity decreases approximately one-fourth.

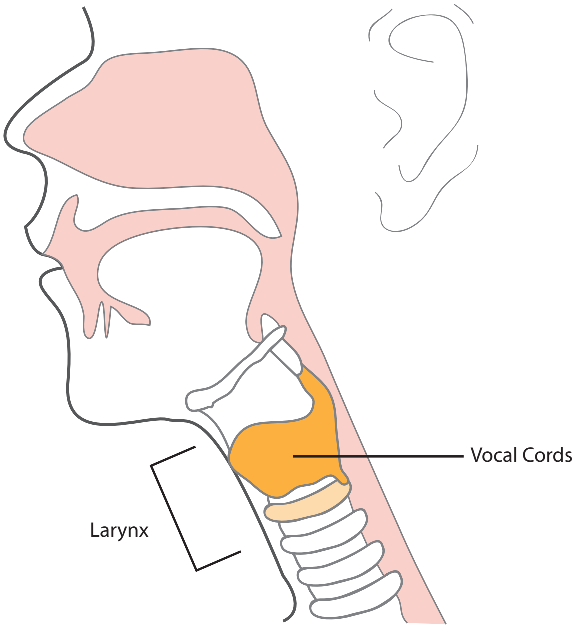

Fig. 1 Vocal cords and larynx

- Some examples of sound intensities as measured by decibels:

Jet plane at takeoff 110-140dB
Loud rock music 110-130dB
Chain saw 110-120dB
Thunderstorm 40-110dB
Vacuum cleaner 60-80dB
Normal voices 50-70dB
Whisper 20-50dB
Purring cat 20-30dB
Falling leaves 10dB
Silence 0dB

Objects have a frequency at which they prefer to vibrate. This frequency depends on its size and of the material of which it is made. This preferred frequency is called the **natural frequency.** The natural frequency is also called the **resonant frequency.** A guitar string is a good example: When plucked it will vibrate at its natural frequency.

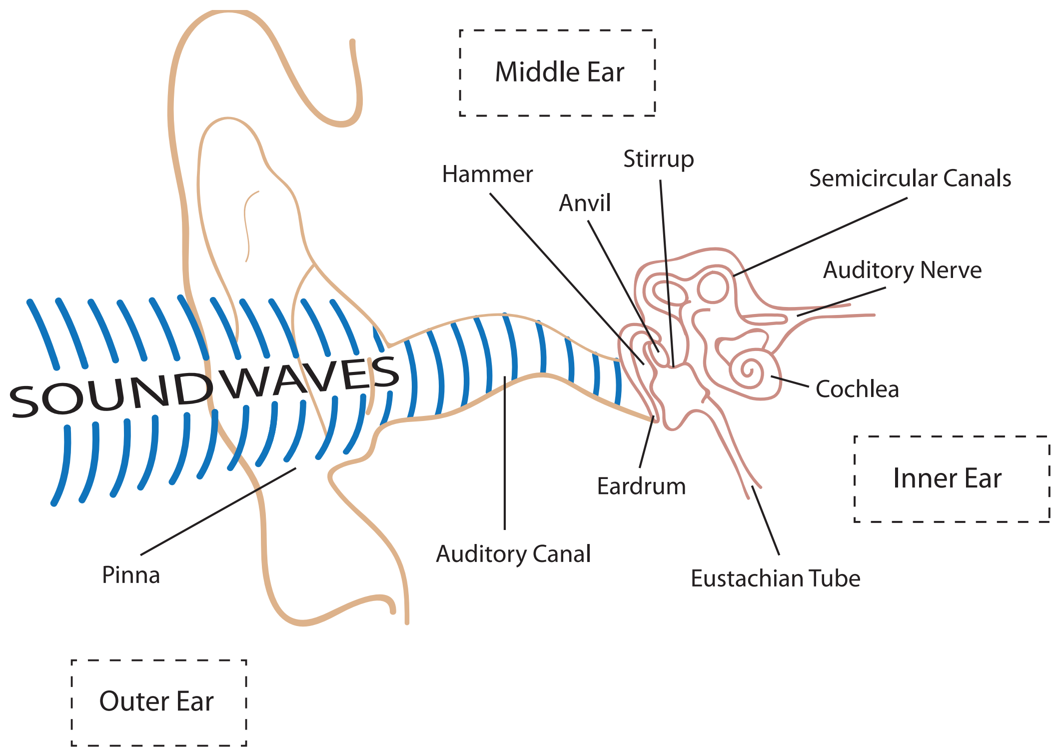

Fig. 2 The human ear

The Human Ear

- The outer ear collects sound waves.
- Sound waves travel down the ear canal and vibrate the eardrum.
- The three small bones (hammer, anvil, stirrup) vibrate behind the eardrum.
- The vibrations enter the cochlea which changes the mechanical energy of the vibrations into electrical nerve impulses that travel to the brain.
- The normal range of sound that a human can hear is about 40 – 18,000 Hertz (Hz).
- As we age, the frequency range tends to narrow; the higher range is most affected.
- Many animals can detect a wider range of sound frequencies than humans can. Dogs can hear higher frequencies than humans; elephants can hear lower frequencies.

For additional information on sound, please review the following Museum in a Box lessons:

Quieting the Popper

Speed of Sound

Seeing Sound

Activity 1 Resonator

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Time Requirements: 45 minutes

Materials:

In the Box

1 stick of modeling clay

2 wood dowel rods, 1/8" diameter, 18" long

1 wood dowel rod, 3/16" diameter, 36" long

1 wood dowel rod, 3/16" diameter, 24" long

1 wood dowel rod, 3/16" diameter, 30" long

2 wood dowel rods, 3/16" diameter, 18" long

Wood base

Safety glasses

7 Sponge balls

Provided by User

Phillips-head screwdriver, or nail

Ruler or measuring tape

Worksheets

Resonator Worksheet: Demonstration 1 (Worksheet 2)

Resonator Worksheet: Demonstration 1 (Worksheet 3)

Post-Lab Analysis (Worksheet 4)

Objective:

Students will learn about motions and forces, and interactions of energy and matter as they gain an understanding of resonance, natural frequency and vibration.

Activity Overview:

Students will understand the concepts of natural frequency and resonance by observing a series of wooden dowel demonstrations. First, four wooden dowels of various lengths are placed in a wooden base, which is then rocked back and forth. The different-size wooden dowels resonate at different times as the frequency of the back-and-forth motion of the base is varied. In the second experiment dowels of different diameters are used and the length is kept constant.

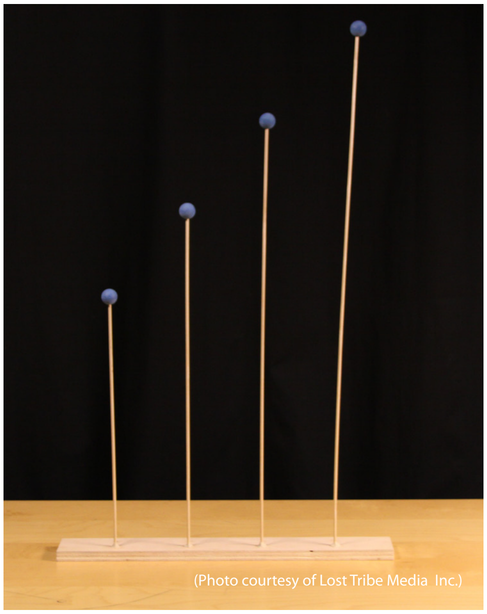
The Flinn Scientific Resonator Demonstration Kit includes a pre-drilled wooden base, pre-cut wooden dowels, 7 sponge balls, sandpaper, and modeling clay. Detailed teacher instructions and student worksheets are provided both in this lesson and in the Flinn instruction sheet.

Wear safety glasses when performing this demonstration. Students sitting or standing near the demonstration also should wear safety glasses. Be cautious when doing the demonstration – the wooden dowels may break if the base is shaken harshly. Follow all laboratory safety guidelines.

Activity:

Demonstration #1 illustrates how the length of a material affects its natural frequency.

1. **Obtain four 3/16" diameter wooden dowels of different lengths (36", 30", 24", and 18").**



Img. 1 Demonstration #1 setup

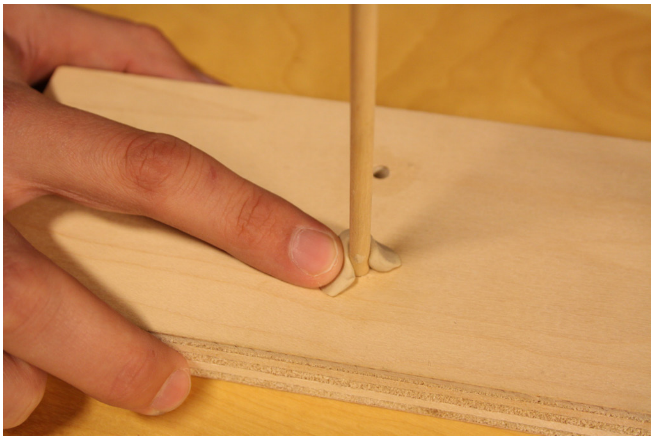
Reference Materials

Image 1
Image 2

Key Terms:

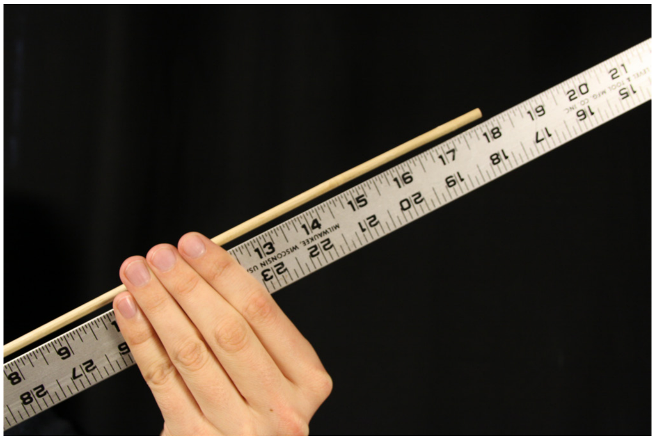
Vibrations
Resonance
Frequency

2. **Place the dowel rods into the four aligned 3/16" holes in the wooden base as show in Image 1.** If a wooden dowel does not fit into its proper hole, the wood may have swelled. Use the sand paper provided to wear down the circumference of the dowel until it will fit into the proper pre-drilled hole.

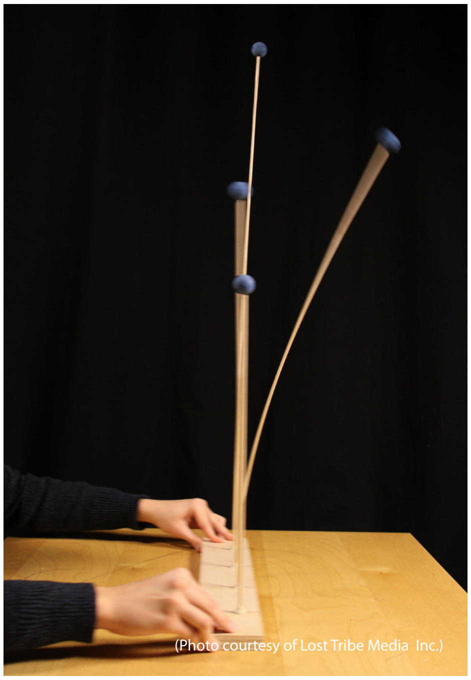


3. **Secure the end of each wooden dowel into the hole in the base by placing modeling clay around the dowel and on top of the base.** Then place the sponge balls on top of the dowels.

4. **Measure the length of each wooden dowel and have students record this information on the proper section of Worksheet 2 Resonator Worksheet: Demonstration 1.**



5. **Place the wooden base on a flat surface and slide the base back and forth (away and toward you) as shown in Image 2.** Start with a low frequency and gradually increase the frequency until only the 36" dowel rod begins to resonate (move back and forth). It will take some practice in order to find the correct timing. When the 36" dowel rod is vibrating vigorously, keep this frequency constant for 10-15 seconds and allow the students to observe. Have students record their observations on the Worksheet 2 Resonator Worksheet: Demonstration 1.



Img. 2 Back-and-forth motion

6. **Gradually increase the frequency of the back-and-forth motions of the base until the 30" dowel rod begins to resonate.** (The 36" dowel will stop resonating.) When this occurs, keep the frequency constant for 10-15 seconds and allow the students to observe and record their observations Worksheet 2 Resonator Worksheet: Demonstration 1.

7. **Again, gradually increase the frequency of the back-and-forth motion of the base until the 24" dowel rod begins to resonate.** Keep the frequency constant for 10-15 seconds and allow the students to observe and record their observations on Worksheet 2 Resonator Worksheet: Demonstration 1.

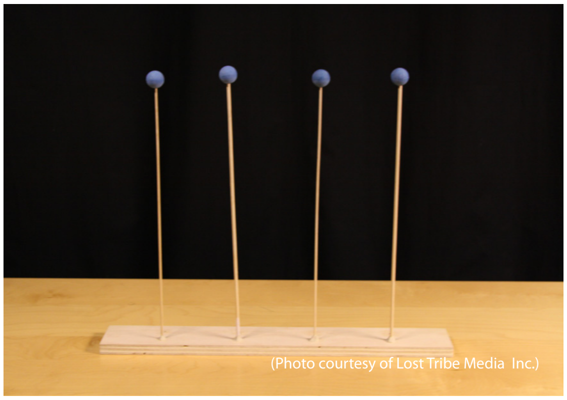
8. **Gradually increase the frequency of the back-and-forth motion of the base until the 18" dowel rod begins to resonate.** Keep the frequency constant for 10-15 seconds and allow the students to observe and record their observations on Worksheet 2 Resonator Worksheet: Demonstration 1.

9. **Remove the wooden dowels and clay from the base.**

Demonstration #2 illustrates how the diameter of a material affects its natural frequency.

1. **Obtain two 18" long wooden dowels that are 3/16" in diameter, and two 18" long wooden dowels that are 1/8" in diameter.**

2. **Place the dowel rods into the proper holes in the wooden base as shown in Image 3.** Place a sponge ball on each of the dowels.

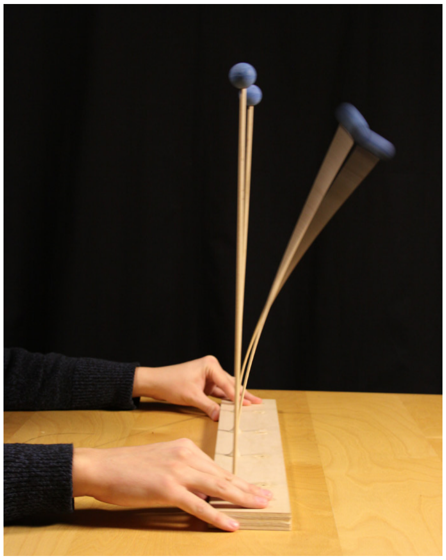


Img. 3 Demonstration #2 setup

3. **Secure the end of each wooden dowel into the hole in the base with some modeling clay.**

4. **Measure the diameter of each wooden dowel and have students record this information on Worksheet 3 Resonator Worksheet: Demonstration 2.**

5. **Place the wooden base on a flat surface and slide the base back and forth as shown in Image 4.** Start with a low frequency and gradually increase the frequency until the 1/8" diameter dowel rods begin to resonate. This will take some practice in order to find the correct timing. When the 1/8" diameter dowel rods are vibrating vigorously, keep the frequency of the base constant for 10-15 seconds. Allow the students to observe and record their observations on Worksheet 3 Resonator Worksheet: Demonstration 2.



Img. 4 Back-and-forth motion

6. **Gradually increase the frequency of the back-and-forth motions of the base until the 3/16" diameter dowel rods begin to resonate.** When the 3/16" rods are vibrating vigorously, keep the frequency of the base constant for 10-15 seconds. Allow the students to observe and record their observations on Worksheet 3 Resonator Worksheet: Demonstration 2.

Upon the completion of demonstration 1 and 2 answer the questions in Worksheet 4 Post-Lab Analysis Worksheet.

Discussion Points:

1. **Choose one of the dowels with an attached ball.** Set it in motion and determine its frequency by counting the number of swings that it makes during a minute. One swing is defined as the ball moving from one side to the other and back again. This can also be referred to as a cycle. The frequency will then be that number of cycles per minute. You can write the frequency using the following notation: for example, if the ball went back and forth 30 times in a minute, you would write the frequency as 30 cycles/min. You could also give this frequency as .5 cycles/sec. For sound, that is a very low frequency – way too low for a human to hear. The threshold for human hearing begins at about 18/sec. Other ways to write the frequency are: 18 cycles per second or 18 Hertz, or 18 Hz.

2. **Ask students if they ever have had something in their car rattle.** Anything that can vibrate has what is called a natural frequency of vibration. If the vibrations produced by the engine or motion of the car matches that natural frequency, then a rattle can occur. NASA engineers must know about resonance in order to design aircraft that do not make a lot of noise.

3. **Relate this activity with the Tuning Fork activity.** The tuning forks have a natural frequency at which they vibrate. Is the length of the tuning fork and the frequency at which it vibrates consistent with the results of the Resonator experiment?

Worksheet 1 Resonator Worksheet: Demonstration 1 Questions/Answers

1. **Record the length of each wooden dowel used in Demonstration 1.**

   36" 30" 24" 18"

2. **Which dowel resonated first (at the lowest frequency)?**

   36", longest

3. **Which dowel resonated last (at the highest frequency)?**

   18", shortest

4. **As a wooden dowel achieved resonance, what did you notice about the other dowels?**

   As a wooden dowel achieved resonance, the other wooden dowels were either vibrating slightly or not moving at all.

5. **At any point during the demonstration, did two or more dowels resonate at the same time?**

   No, two or more dowels did not resonate at the same time. As one dowel resonated, the others were motionless or vibrating slightly.

6. **Other than the length of the dowel, what variable affects the resonance of each dowel?**

   The frequency of the back-and-forth motion determines which dowel will resonate.

Worksheet 2 Resonator Worksheet: Demonstration 2 Questions/Answers

1. **Record the diameter and length of the wooden dowels used in Demonstration #2.**

   All dowels in this demonstration are 18″ long. The diameters of the thin dowels are 1/8″, and the diameters of the thick dowels are 3/16″.

2. **Which dowel(s) resonated first (at the lowest frequency)?**

   The 1/8″ thin dowels resonated first when the instructor started moving the base.

3. **Which dowel(s) resonated last (at the highest frequency)?**

   The 3/16″ dowels resonated last.

4. **At any point during this demonstration did two or more dowels resonate at the same time? Explain your observation.**

   Yes, the wooden dowels that have the same diameter resonate together. Therefore, they have the same natural frequency.

5. **What caused the different dowels to resonate at different times?**

   The instructor changed the frequency of the back-and-forth motion of the base in order to resonate different dowels.

Worksheet 3 Post-Lab Analysis Worksheet Questions/Answers

1. **Based on your observations in Demonstration #1, do any of the dowels share the same natural frequency? Explain your answer.**

   No, the dowels do not share the same natural frequency. They all resonate at different frequencies.

2. **Based on your observations in Demonstration #2, do any of the dowels share the same natural frequency? Explain your answer.**

   Yes, wooden dowels that have the same diameter and length resonate together. Therefore, they have the same natural frequency.

3. **What characteristics are necessary in order for two dowel rods to resonate at the same time?**

   Wooden dowels must have the same length and diameter in order to resonate together.

4. **Using the same dowels provided in this demonstration kit, describe how an experiment could be set up to test if dowels of different lengths and different diameters share the same natural frequency.**

   Individually test each of the 3/16" diameter wooden dowels next to the 18" long 1/8" diameter dowel. Observe if any of the 3/16" dowels resonate at the same time as the 1/8" dowel when the base is moved back-and-forth. If resonance occurs, the two dowels share the same natural frequency.

5. **Describe the relationship between the length of an object and the frequency causing the object to resonate.**

   The longer an object, the lower the frequency needed to cause resonance.

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Reference Materials

Glossary

Decibel:
Unit of sound intensity

Frequency:
The periodic change in sound pressure; frequency is measured in cycles per second or in Hertz (Hz)

Hertz (Hz):
The unit used when designating frequency; cycles per second

Intensity:
The average rate at which sound energy is transmitted through an area between a source and a receiver; sound energy is measured in watts/cm2 or in decibels (dB)

Interference:
Regarding sound waves, when two waves of the same, or nearly the same, frequency pass through the same region of space, they interact with each other and cause interference; interference can be either constructive or destructive, depending on how the waves interact

Noise:
Sound with no set patterns in rhythm or frequency; a random mixture of frequencies

Pollution:
The contamination of soil, water, or air with substances, or sounds, that do not belong

Pitch:
The highness or lowness of a sound

Resonance:
The vibration of an object when exposed to sound at its own natural frequency, as in a window pane vibrating when a helicopter flies overhead

Vibrations:
The back-and-forth motion of an object, usually rapid; when referring to sound, many different "objects" can vibrate, such as a guitar string, a column of air, the reed in a clarinet, or your vocal chords

Worksheets

Worksheet 1 Resonator Worksheet: Demonstration #1

1. **Record the length of each wooden dowel used in Demonstration 1.**

2. **Which dowel resonated first (at the lowest frequency)?**

3. **Which dowel resonated last (at the highest frequency)?**

4. **As a wooden dowel achieved resonance, what did you notice about the other dowels?**

5. **At any point during the demonstration, did two or more dowels resonate at the same time?**

6. **Other than the length of the dowel, what variable affects the resonance of each dowel?**

Resonator Worksheet: Demonstration #2

1. **Record the diameter and length of the wooden dowels used in Demonstration #2.**

2. **Which dowel(s) resonated first (at the lowest frequency)?**

3. **Which dowel(s) resonated last (at the highest frequency)?**

4. **At any point during this demonstration did two or more dowels resonate at the same time? Explain your observation.**

5. **What caused the different dowels to resonate at different times?**

Worksheet 3 Post-Lab Analysis

1. **Based on your observations in Demonstration #1, do any of the dowels share the same natural frequency? Explain your answer.**

2. **Based on your observations in Demonstration #2, do any of the dowels share the same natural frequency? Explain your answer.**

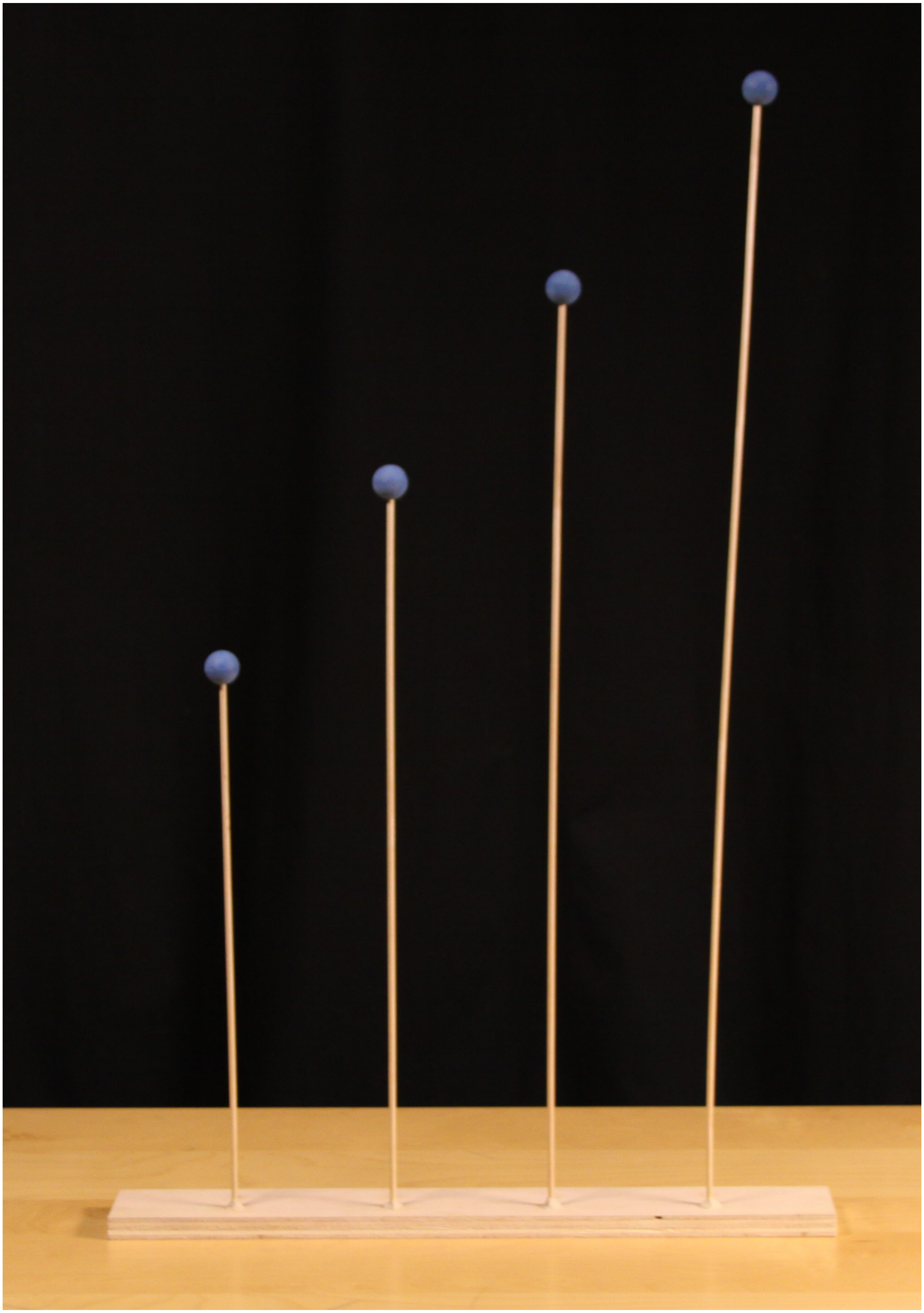
3. **What characteristics are necessary in order for two dowel rods to resonate at the same time?**

4. **Using the same dowels provided in this demonstration kit, describe how an experiment could be set up to test if dowels of different lengths and different diameters share the same natural frequency.**

5. **Describe the relationship between the length of an object and the frequency causing the object to resonate.**

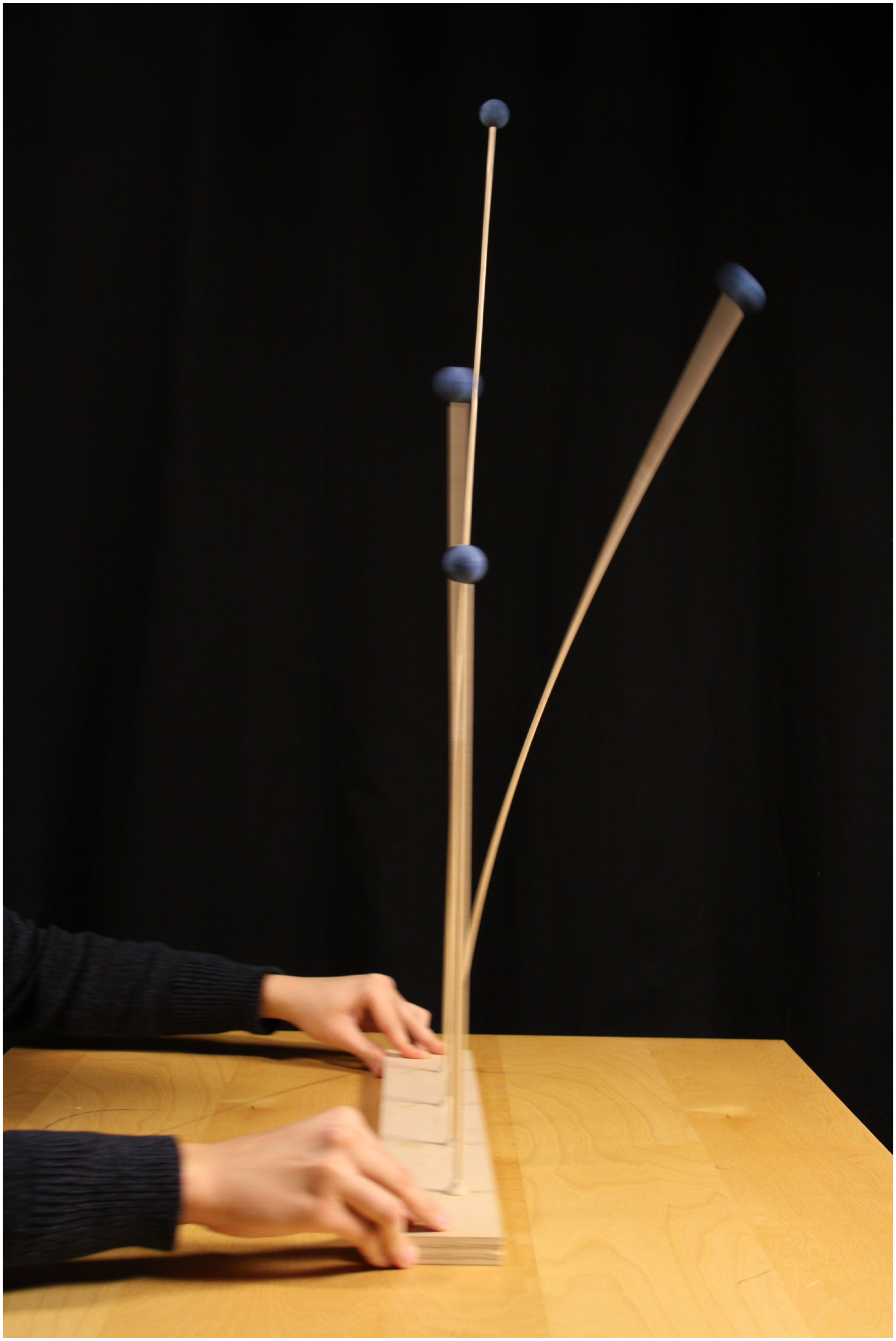
Images

Img. 1 Demonstration #1 setup



(Photo courtesy of Lost Tribe Media, Inc.)

Img. 2 Back-and-forth motion



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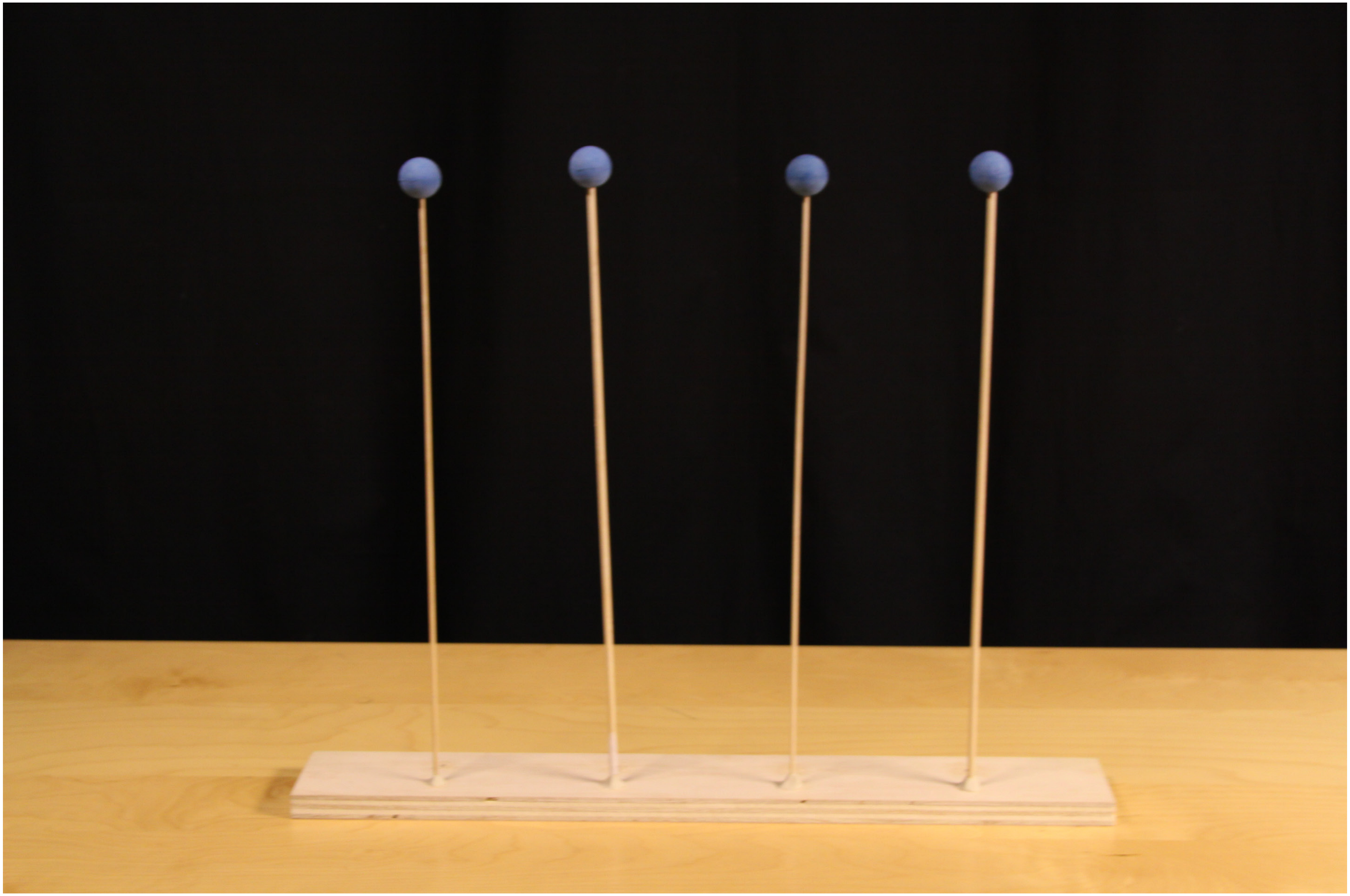
Img. 3 Demonstration #2 setup



(Photo courtesy of Lost Tribe Media, Inc.)

Img. 4 Back-and-forth motion

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