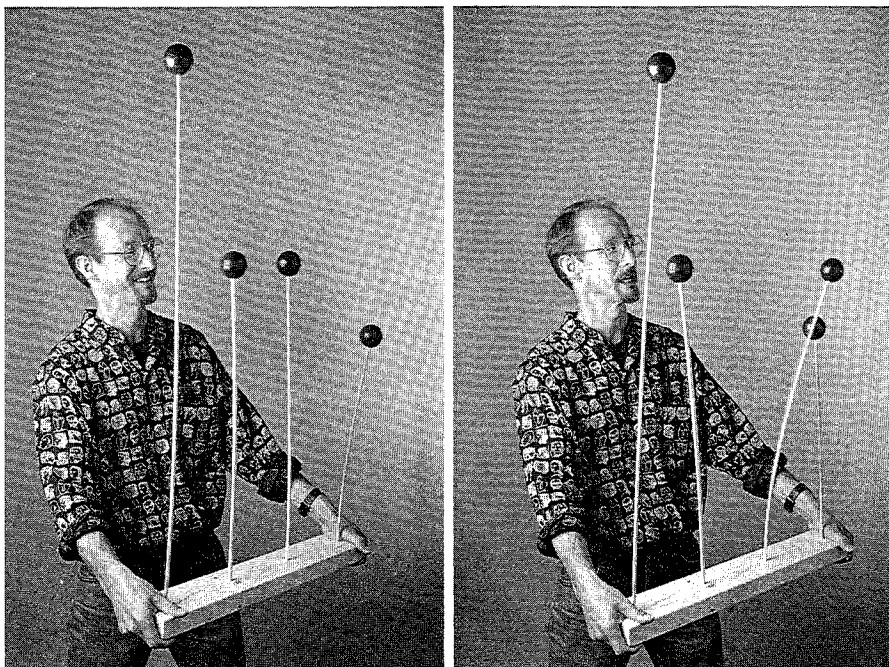


Resonator

If you vibrate something at just the right frequency, you can get a big reaction.



Materials

- **Three 1/4" wooden dowels** measuring 1½ long, 2' long, and 2½ long.
- **One 3/8" dowel** measuring 2' long.
- **4 superballs** (or, if you can't find superballs, you can substitute tennis balls or lumps of clay).
- **One 2 x 4** measuring approximately 2' long.
- **Drill.**
- **Optional:** Carpenter's glue.

Introduction

In this demonstration, wooden dowels of varying lengths, each loaded with the same mass, are vibrated at identical frequencies. When the vibration matches the *resonant frequency* of one of the dowels, that dowel vibrates with a large amplitude. If you vibrate an object near one of its *natural frequencies*, its motion may grow to quite large values, a process known as *resonance*. Spectacular examples of resonance include the collapse of the Tacoma Narrows Bridge in a windstorm and the destruction of buildings during earthquakes.

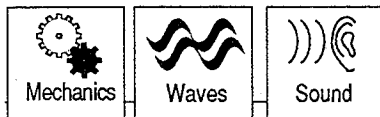
Assembly

Drill four holes approximately 4" apart along the center line of the wide face of the 2 x 4. The first three holes should be slightly smaller than 1/4" and the fourth hole should be slightly smaller than 3/8". Gently hammer the dowels into the holes so that they are held firmly in place. (If you prefer, you can drill holes that are the same size as the dowels and glue the dowels into the holes with carpenter's glue.)

Drill a 1/4" hole halfway through three of the superballs, and a 3/8" hole halfway through the fourth superball. The best way to do this is to place the balls in a good vise and to drill slowly.

Place a superball on the end of each dowel. The superball adds a relatively large mass to each dowel.

The experiment will work even if you don't put superballs on the dowels, but the balls lower the resonant frequencies and make the motion easier to see. You can also substitute tennis balls or lumps of clay for the superballs. Since the center of a tennis ball is hollow, the ball tends to flop around on the end of the dowel.



Mechanics

Waves

Sound

Resonator

Etc.

Just as each dowel has its natural frequencies of vibration where resonance occurs, so most objects tend to vibrate at certain frequencies. You may have noticed that parts of your car rattle at a certain speed or that certain objects vibrate and buzz in response to a particular note from your stereo. These are everyday examples of resonance.

Resonance has also been responsible for some spectacular destruction. In earthquakes, buildings are often damaged when the frequency at which the ground is shaking comes very close to or matches one of the resonant frequencies of the buildings. The Tacoma Narrows Bridge vibrated itself to pieces when wind pushed it at just the right frequency. The wing of the Lockheed Electra Jet failed repeatedly until engineers discovered that the wing's resonant frequency was responsible for its destruction. A suspended walkway at a Kansas City hotel collapsed when people dancing on the structure caused resonant vibration. In the army, troops always march across a bridge out of step; army vehicles are spaced at irregular intervals when crossing a bridge. These practices avoid setting up vibrations at the bridge's resonant frequency.

Not all objects resonate. Any object that dissipates energy faster than the energy is added will not resonate. Try, for example, shaking the dowels under water. The friction of the dowel moving through water will dissipate the energy faster than you add it. Since the motion of the dowel will not build up at any frequency, there is no resonance.

To Do and Notice

Grip the 2 x 4 at each end and slide it back and forth across a table top, moving it lengthwise. As you vary the rate of shaking, different dowels will swing back and forth with greater or lesser amplitude. When you are shaking at just the right frequency to cause one dowel to vibrate violently, another dowel may hardly be vibrating at all.

Notice which dowels vibrate violently at lower frequencies and which vibrate violently at higher frequencies. CAUTION: If you get the dowels vibrating too violently—watch out!—they may break!

What's Going On?

When you push a child on a swing, a series of small pushes makes the child swing through a large amplitude. To accomplish this, you time your pushes to match the swing's natural frequency, the rate at which the swing tends to move back and forth.

The same principle is at work in this demonstration. When you shake the 2 x 4 assembly at just the right frequency, a series of small shakes adds up to a large vibration of a particular dowel. The shaking board sets the dowel vibrating. If the next shake is timed just right to reinforce the next vibration of the dowel, the vibration in the dowel builds up. This process of using a series of small inputs to create a large motion is known as resonance.

The longer the dowel, the more slowly it tends to vibrate—the lower its natural frequency. Thus, the long dowel will resonate at lower frequencies than the short dowel.

Stiffer dowels have higher resonant frequencies. The 3/8" dowel is much stiffer than the 1/4" dowels, and so it tends to resonate at higher frequencies than the thinner dowels.

Each dowel may have more than one resonant frequency.