

EQUIPMENT BUILD PLAN

SOUND & WAVES

Standing Wave Gadget

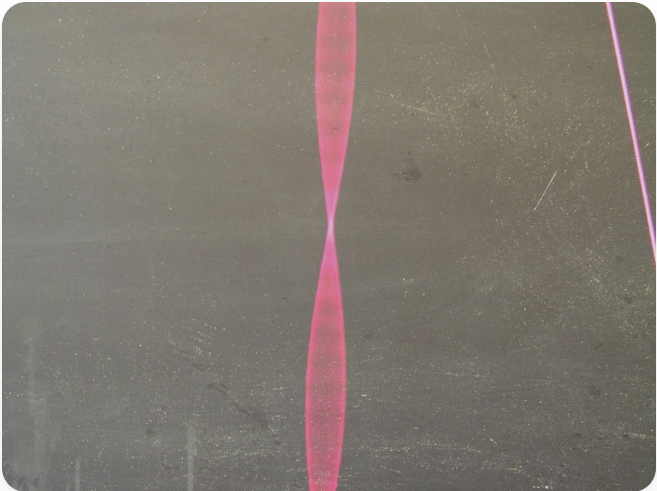
A small motor with an off-center weight on its shaft is housed in a PVC plug and hung from the bottom of a long string. Its wobble sends waves up the string that reflect from the top support; adjust the length and the string locks into a clean standing wave with distinct nodes and antinodes. It is cheap enough to build one per lab group and supports both a quick demonstration and real measurements of wave speed.

Written from Bruce's original workshop
handout. Bruce's final review of this plan is in
progress.

What it shows

A one-battery motor hanging on a string turns a plain cord into a row of glowing, motionless loops.

Key ideas: standing waves, nodes and antinodes, harmonics, wave speed, tension, linear density



<div>DIFFICULTY</div> <div>Intermediate</div>	<div>BUILD TIME</div> <div>1-2 hours</div>
<div>COST</div> <div>About \$10</div>	<div>SAFETY</div> <div>Adult build / supervision</div>
<div>GOOD FOR</div> <div>Teachers, Makers</div>	

Safety (Adult build / supervision). The off-center weight spins very fast. Make sure it is pressed firmly onto the motor shaft (and, if you use a bolt-and-nut weight, that the nuts are threaded all the way on) and check it before every use so nothing flies off. An adult should

do the drilling and soldering. Keep faces away from the spinning end.

CONSTRUCTION

Build it

Materials

- ☐ **Small DC toy motor** · 1
Must fit snugly inside the PVC plug
- ☐ **Single AA battery holder** · 1
Plus an AA battery
- ☐ **PVC plug, 1 in** · 1
Forms the housing
- ☐ **Eyebolt, 2 in long, with 2 nuts** · 1
The string ties here; extra weights can be clamped between the nuts
- ☐ **#4 screws, 1/2 in long** · 2
Hold the battery holder to the plug
- ☐ **Wood strip, about 3 in by 3/4 in** · 1
Becomes the off-center weight on the motor shaft
- ☐ **Nylon string, braided** · 20 ft
Braided string works better than twisted
- ☐ **Small slide switch (optional)** · 1
Otherwise the battery is the on/off switch
- ☐ **Washers or slotted masses** · A few
For changing the tension

Tools

Drill with small bits, including 1/16 in

Soldering iron and solder

Wire strippers

Small screwdriver

Pliers

1

Drill the eyebolt hole

Drill a hole in the center of the closed end of the PVC plug, one size smaller than the eyebolt, so the bolt can be screwed in tightly.

2

Drill a wire hole

Drill a second, smaller hole toward the side of the plug's closed end. The motor wires will come up through it.

3

Mount the battery holder

Set the battery holder on top of the plug beside the center hole. Drill two holes through the holder, then drill matching 1/16 in pilot holes down into the plug wall, and fasten it with two #4 × 1/2 in screws.

4

Install the eyebolt

Thread both nuts onto the eyebolt and screw it into the center hole. The space between the nuts will later hold washers or slotted weights.

5

Seat the motor

Feed the motor's wires up through the side hole and push the motor into the open end of the plug, shaft pointing down. If it is loose, wrap a little tape around it for a tight fit.

6

Wire it up

Trim the battery-holder leads short. Solder one motor wire to each battery-holder lead (add a slide switch in one lead if you like). With no switch, you turn it on and off by inserting and removing the battery.

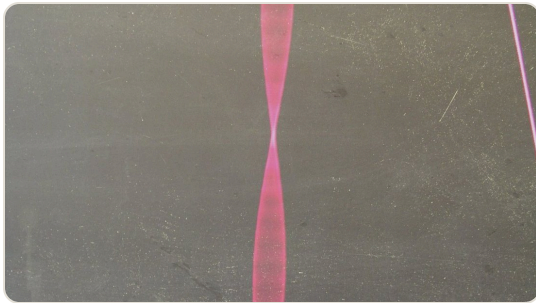
7

Make the off-center weight

Drill a hole near one end of the wood strip so it is a tight push fit on the motor shaft, and press it on. Extra holes at different spots let you change the speed and size of the wobble.

Hang and test

Tie the string to the eyebolt and hang the gadget from a high support, or hold the string a foot or two above it. Switch it on, let it settle, then slowly lengthen the string until a steady standing wave appears.



THE PHYSICS

How it works

The spinning off-center weight makes the bottom of the string wobble many times a second. Each wobble sends a wave up the string. At the top support the wave reflects and travels back down, overlapping with the new waves coming up.

At most lengths the up-going and down-going waves jumble together. At certain lengths they line up so that some points always cancel (nodes) and the points halfway between swing widely (antinodes). That steady pattern is a standing wave. Adjacent nodes are half a wavelength apart.

Wave speed on a string depends on tension T and mass per length μ : $v = \sqrt{T / \mu}$. Here the tension is simply the weight of the hanging gadget. Wave speed also equals frequency times wavelength, $v = f \times \lambda$. Adding weight raises the speed, so with the same motor frequency the wavelength gets longer and you need more string for the same number of loops.

Using it

- **Demonstration:** lengthen the string slowly and count how the number of antinodes steps up, from one to more than twenty with a stairwell or ceiling hook.
- **Tension:** set up four antinodes (two full wavelengths), measure node-to-node distances, then clamp washers between the eyebolt nuts and measure again.
- **Frequency:** move the wood weight to a different hole, or change the weight on the shaft, and compare wavelengths.
- **Linear density:** try different strings or cords and compute $\mu = \text{mass} / \text{length}$ for each.
- **Two-way check:** weigh the gadget to get T , compute $v = \sqrt{T / \mu}$, then measure f with a strobe or photogate and λ from the

string and compare with $v = f \times \lambda$.

- With a strobe light in a darkened room, the string can be made to appear to rotate slowly or freeze.

GO FURTHER

Variations

- Use a small nylon bolt with two nylon nuts on the shaft as the off-center weight; removing or moving a nut changes the frequency. If you remove a nut, tape it to the housing so the total weight (and tension) stays the same.
- Shock cord instead of string: its linear density changes as it stretches. Mark two points on the slack cord, measure them again when stretched, and divide the slack linear density by the stretch ratio.

IF IT DOESN'T WORK

Troubleshooting

IF THIS HAPPENS

The pattern keeps shifting

TRY THIS

Make small changes to the string length and give it a few seconds to settle after each change.

IF THIS HAPPENS

Nodes are fuzzy

TRY THIS

Adjust the length until the antinodes are as large as possible and the nodes are as small as possible; fresh batteries keep the frequency steady.

IF THIS HAPPENS

Motor slips in the housing

TRY THIS

Wrap tape around the motor until it fits tightly in the plug.

IF THIS HAPPENS

Weight works loose on the shaft

TRY THIS

Redrill a tighter hole or use a new strip; never run it loose.

© Bruce Yeany · Homemade Science with Bruce Yeany · youtube.com/@YeanyScience

Free for personal and classroom use. Please don't resell or republish. Build and use at your own risk; follow the safety notes and supervise children.