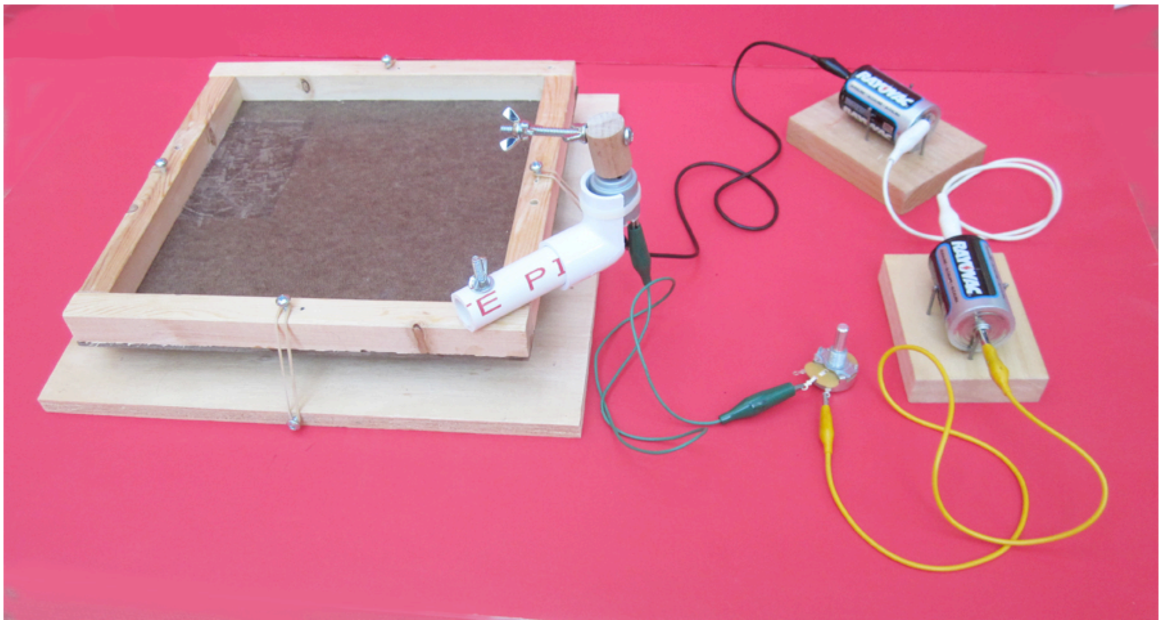
Shake Table
Will the walls come tumbling down?

A small battery-powered motor with an off-center mass on its shaft is attached to a platform which is mounted in such a way that it is free to vibrate when the mass is rotating. Structures may be placed on the vibrating platform to simulate behavior in an earthquake. Marbles, beads or metal shot may be placed on the vibrating platform to simulate molecular motion or packing.



Materials

1 piece plywood, 3/8” or thicker, 12” x 12”
1 piece masonite, 1/8” thick, 10” x 10”
2 pieces wood, 3/4” x 3/4”, 10” long
2 pieces wood, 3/4” x 3/4”, 8 1/2" long
8 sheet metal screws, #8 x 5/8”, pan head, Phillips
4 rubber bands, #16
4 plastic bottle caps from bottles such as soda bottles, water bottles, etc. (see Assembly Step 1 for discussion of suitable caps)
4 marbles (all the same size, with diameter larger than the height of the bottle cap wall, and able to roll freely in the bottle cap -- a fairly common marble diameter is about 5/8”)
1 PVC pipe, 1/2", Schedule 40, 3 in long
1 PVC elbow, 1/2"
1 small electric motor, 1.5–6 volts, e.g. Kelvin 850647
1 cable tie, 8"
1 wooden dowel, 3/4" diameter x 1" long
2 machine screws, 10 - 24 x 2 1/2”" long
4 wing nuts, 10 - 24
2 flat steel washers, SAE 10
5 flat steel washers, USS 3/8”
2 batteries, 1.5 volt, D cell
2 wood blocks, 2" x 4 " x 3/4" (big enough for D cell; exact size not critical)
8 finishing nails, 1 1/2"
1 potentiometer, 20 or 25 ohm
4 alligator clip leads, approximately 12” long
electric drill
3/16" drill bit
1/8” drill bit
American Wire Gage #50 drill bit or 1/16" drill bit (AWG 50 is preferable -- see Assembly Step 7 for discussion)
screwdriver, Phillips
hammer
hot glue gun and hot glue sticks

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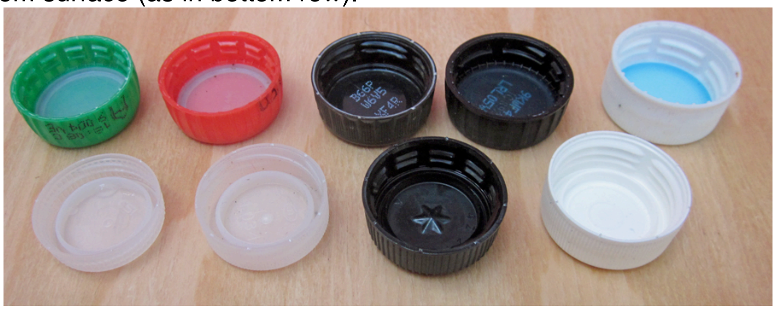
Assembly

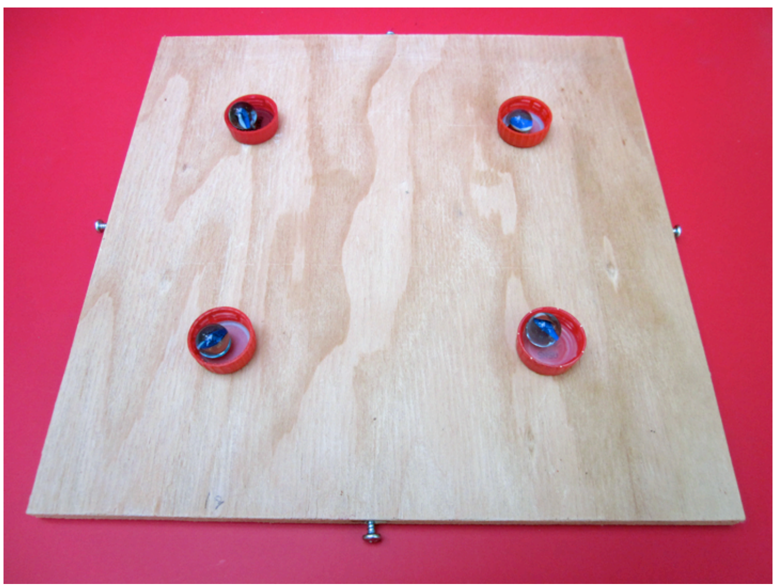
1. Hot-glue the four plastic bottle caps to the base 3 inches inside the edges of the base, with the open side of the cap facing upward. See photo following Step 3.

(Note: The photo immediately below shows several different types of caps. In general, caps which provide a large flat inside bottom surface for a marble to roll on (as in the top row in the photo here) are preferable to caps with an uneven or obstructed bottom surface (as in bottom row).



2. Use the 1/8" drill bit to drill pilot holes horizontally into the middle of each of the four edges, and drive one of the sheet metal screws into each of the four holes. Don't drive the screws all the way in -- leave about 1/4" of thread showing. See photo following Step 3.

3. Put a marble in each of the caps. Be sure the marble diameter is larger than the height of the cap wall. See photos below.



4. Use hot glue to attach the four pieces of wood to the top surface of the piece of masonite to form a rim around the edges. See photo following Step 6. (Note: if one side of the masonite is smooth and the other rough, have the smooth side facing up.)

5. Use the 1/8" drill bit to drill pilot holes vertically into the middle of the top of each of the four pieces of wood, and drive a screw into each of the four holes. Don't drive the screws all the way in -- leave about 1/4" of thread showing. See photo following Step 6.

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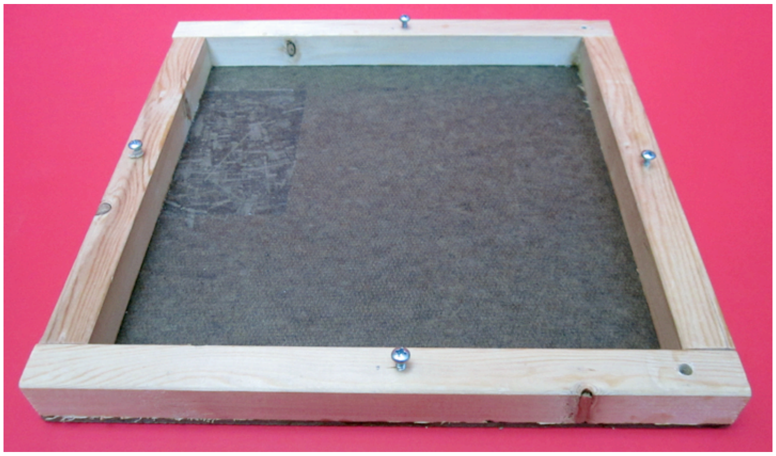
6. Use the 3/16” drill bit to drill a vertical hole in one corner of the platform all the way through the platform. See photo below for hole placement; in the photo the hole is in the lower right corner and is 3/4” from the right edge of the wooden rim.



7. Use the American Wire Gage #50 drill bit to drill a hole in one end of the wooden dowel, and the 3/16" drill bit to drill a hole across the dowel near the other end. Insert the motor shaft into the small hole in the end of the dowel. See photo and NOTE below.

NOTE: The American Wire Gage (AWG) #50 drill bit is an uncommon size. It's between the two common sizes of 1/16” and 5/64”. If you don’t have access to an AWG 50, you can use a 1/16” drill bit, but it’s very hard to get the motor shaft in the smaller hole, and the larger 5/64” hole may allow some eventual slipping of the shaft in the hole and/or allow the dowel to come off the shaft during use. If you use a 1/16” bit, use the following procedure. Hold the motor so that the short end of the shaft (which protrudes from the plastic end cap) is resting on a hard surface and the long shaft on the other end is sticking straight up from the motor. Press the **DOWEL DOWN ONTO THE MOTOR SHAFT** so that the shaft fits into the hole. (**CAUTION**: If the fit is tight and you try to push the **motor shaft down into the dowel,** you may pop the motor right out of its casing!)

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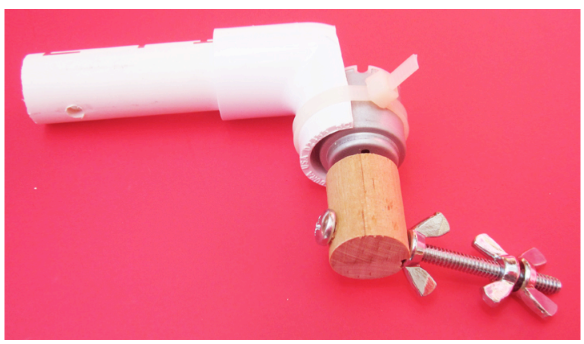
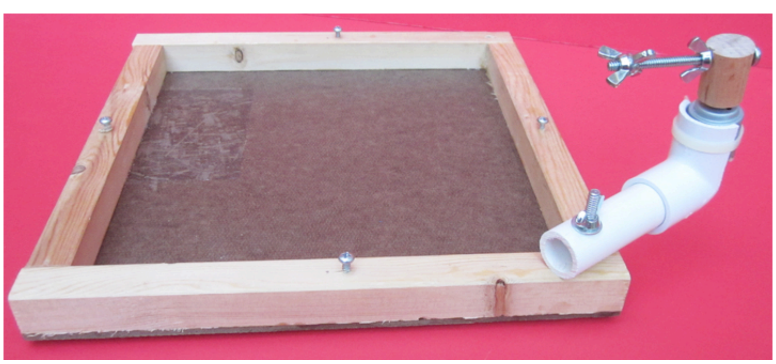
8. Use a band saw to cut the PVC elbow as shown in the photo below.

9. Use the 3/16” drill bit to drill a hole all the way through the PVC pipe (both walls) near one end. See photo below.

10. Place a machine screw and 3 wing nuts on the dowel, insert the non-drilled end of the PVC pipe into the PVC elbow, and use the cable tie to attach the motor to the elbow. See photo below.



11. Attach the complete motor assembly shown in the previous photo to the masonite-wood platform by placing one of the small washers on the remaining machine screw and pushing the screw up from the bottom of the platform and through the two holes in the PVC pipe. Put the remaining small washer and remaining wing nut on the protruding end of the machine screw and tighten the wing nut to hold the motor assembly firmly in place. See photo below.



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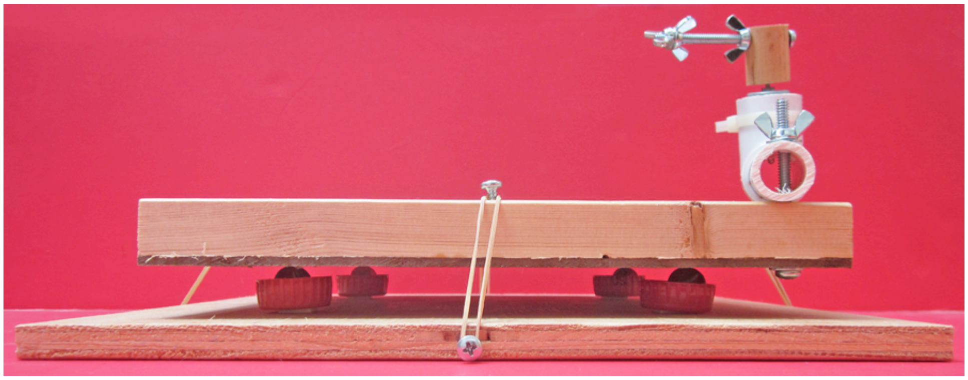
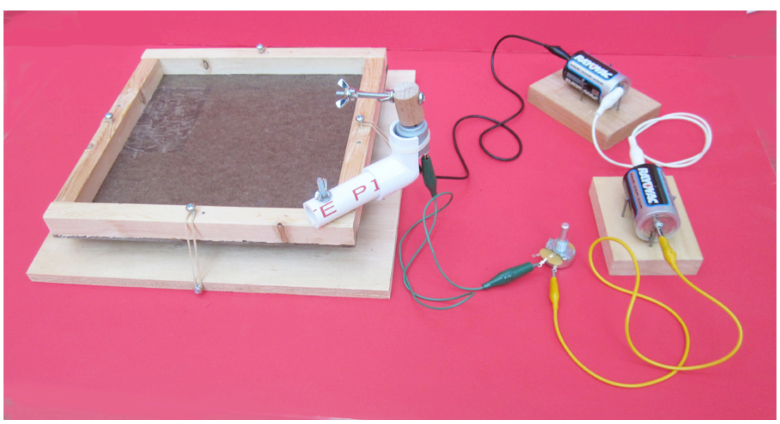
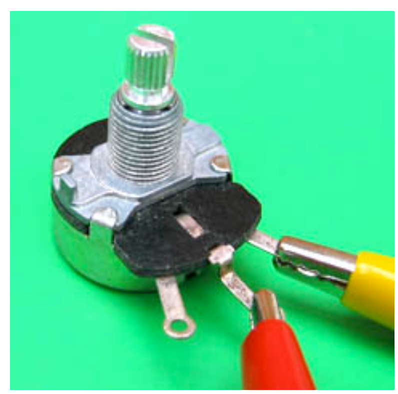
12. Lay the platform with motor assembly on the marbles in the caps on the base, and put a rubber band around each of the four corresponding pairs of screws. See photo below.



13. Use the wood blocks and finishing nails to make two battery holders as shown in the photo below.

14. Use the alligator clip leads to hook up the batteries, motor and potentiometer in a series circuit The clips should be attached to the middle tab and either of the end tabs on the potentiometer (the potentiometer is used to control the motor speed). See photos below.





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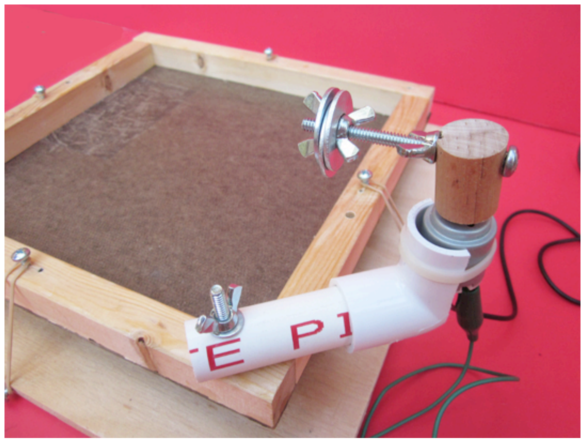
Notes and Comments on Operation

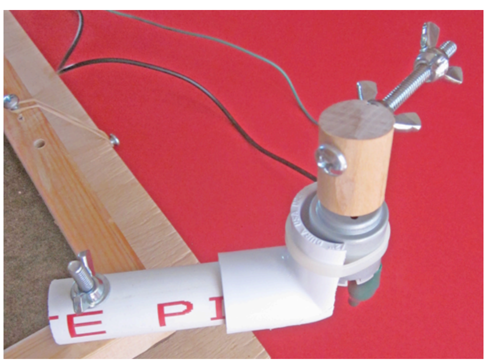
To obtain the shaking motion that suits your purpose, you can experiment with the variables noted below.

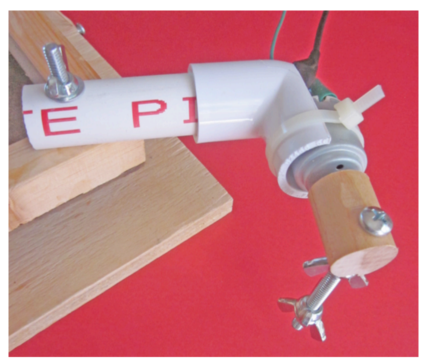
Speed of the motor
Speed is controlled by the potentiometer.

Amount and location of mass on the machine screw
The amount and location of mass on the machine screw can be adjusted with the two outer wing nuts. To get a smaller mass you can remove one or both. To increase mass you can add washers between the wing nuts (see photo below). You can also try other size washers. You can adjust the position of the mass by moving the wing nuts either closer in or farther out on the machine screw.



Position of the motor
You can pivot the PVC pipe around the screw through the masonite top, allowing the position of the whole motor assembly to be changed -- also, the elbow rotates on the end of the pipe, allowing the machine screw "eccentric" to rotate in a horizontal circle (left photo below) or vertical circle (right circle below) or in between





You are encouraged to experiment with these and other variables (e.g., size and number of rubber bands), and to create improved versions of the shake table based on your experiences. If you come up with an improved design, or develop activities that work particularly well, please let us know!

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To Do and Notice

Blocks, etc.

Stand a variety of wooden blocks on the shake table and investigate how well they stand up when the table is vibrating at various speeds and with different masses on the rotating arm. Try blocks with different heights, different size bases, etc. Other objects to try include marker pens and paper towel tubes. For the mass on the rotating arm, you might consider starting with no washers, and then trying 3 washers for comparison.

Structures

Design and test structures using materials such as straws, pasta, toothpicks, bamboo skewers, etc. as structural members and things like small marshmallows, spice drops, and paper clips as joiners. You can also use modeling clay, marshmallows or spice drops as loads placed at various locations.

Resonance

Look for the presence of resonance as the table shakes. For a particular combination of motor speed and mass adjustment, a shaking object or structure may be almost still, while for other motor settings it vibrates wildly. One structure may topple under conditions that hardly cause another to vibrate.

What's Going On?

When the unbalanced, or "eccentric", load on the motor (the wing nuts on the machine screw) is rotated, it tends to cause the motor itself, and anything the motor is attached to vibrate, very similar to how a spinning tub on a washing machine (and possibly the whole washing machine itself) tend to vibrate during the spin cycle if the distribution of the load of clothes in the tub is significantly uneven.

Different objects, with different shapes and different distribution of mass, behave differently when subjected to vibration. For a particular object there may be a point at which the frequency and mode of vibration is just right to cause maximum motion of the object. This is the "natural frequency" for the particular object, and the behavior is known as resonance.

Going Further

Seismology

Use smart phone seismology and acceleration apps to obtain data for shake table vibrations. Place the phone on the vibrating shake table and observed the readings.

Demonstrate the principle of a seismograph by taping a strip of paper to the shake table, and then moving a pen straight along the paper while the table is vibrating (roller- ball or fiber-tip pens work well, since you don't have to exert much pressure to get them to mark)

Liquefaction

Try using a small container of wet sand to demonstrate liquefaction. Place an object in the container to see if it will "sink."

Molecular Motion

Simulate molecular motion using beads, ball bearings or metal shot, small pieces of PVC, marbles, small rubber balls, etc.

Credit

Shake tables have a long history involving countless designs and designers. For contributions (from 2001 to the present) to the particular evolutionary incarnation in this write-up, credit and thanks go to the following individuals, along with any others inadvertently omitted: Pier Sun Ho, Coral Clark, Carey Linder, Andy Coblentz, John Lahr, Eric Muller, Zeke Kossover.

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