John B. Johnston, The Faraday Center, 103 Creamery Rd., Livingston Manor, NY 12758
(845) 439 - 4706

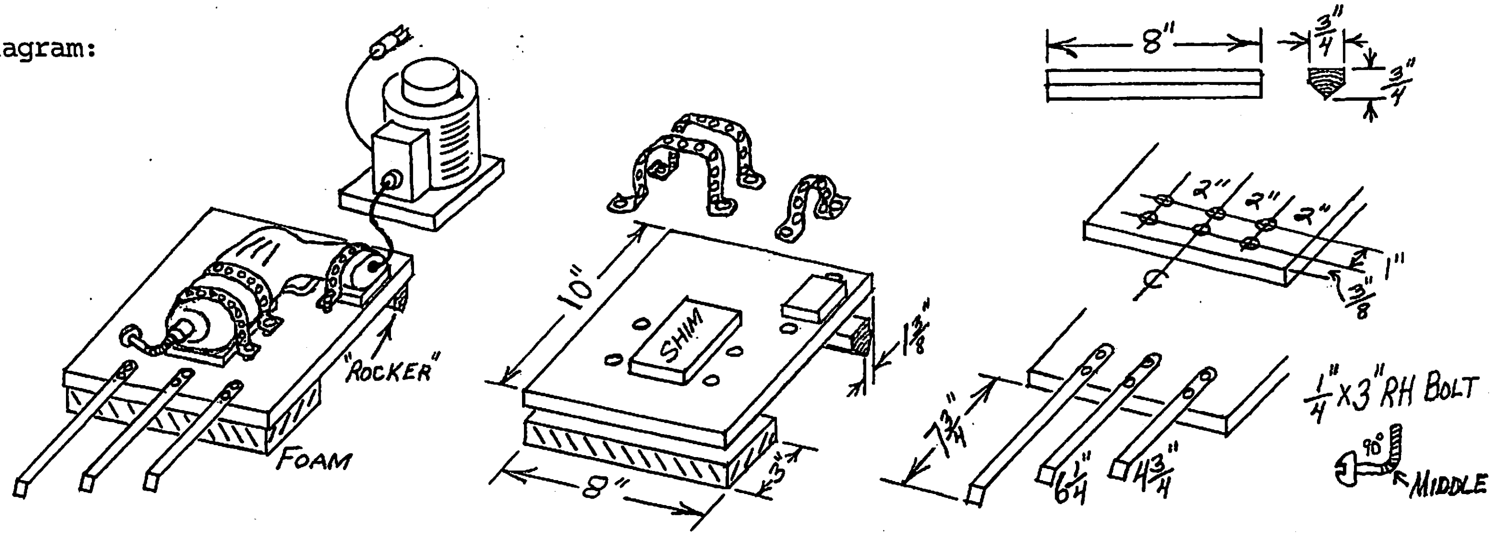
Resonance - is one of the most important concepts in physics (and in life) that does not receive enough attention. This demonstration will define and clarify it. From the beginning, this demo has been my favorite. It was shown to me by NY City's Herb Gottlieb, an outstanding physics demonstrator in the second half of the 20th century. My version only uses a smaller board. Strap a corded electric hand drill to the board; the drill plugs into a Variac for speed control (rpms). Attach three hacksaw blades of different lengths, some foam, and a "rocker" strip to the board as shown in the diagram. Add a bent bolt to the chuck to make the drill "eccentric", and you're done; it's that simple! First, all blades and all drills are not alike. Try to use saw blades of the same make (company). You may have to experiment with their length depending on the blades' stiffness and the drill's range of rpms. An old, single (high) speed, $\frac{1}{4}$" drill is highly recommended for this demo, not the lower speed 3/8" drill. Try to get one ASAP, as they are becoming scarce in this cordless era. (I use an original B&D U-3, 2.5amps, 2250rpm.) In the addendum, I suggest that the same vibrating platform can be used for two other interesting demos. Thus, it is definitely worth the effort to build this one platform that can possibly perform three demos.

Construction: Start with a platform (board) of 3/4" plywood, 8" x 10". Bend a $\frac{1}{4}$" RH bolt according to the diagram to become the "eccentric". Insert the bent bolt in the chuck, tighten, and lay the electric hand drill on its side on the platform to determine where the iron straps and their bolt holes should be located. By hand, rotate the chuck with the bent bolt to make sure the bolt head clears the platform. Insert (glue?) a shim(s) under the drill to insure clearance if necessary. Using tin snips, make up three steel straps (3/4" steel hanger strap) to fasten the drill to the platform. To measure the strap lengths accurately, including the six tips (with one hole) bent up about 90° , use a tailor's flexible tape measure. The straps must fit the drill snugly; this is done by cutting and bending the straps a little "short" to provide tension when tightening them down. (I add a strip of inner-tube rubber under the strap to protect the drill's finish.) With the drill in place, press the straps around it and mark the bolt holes to be drilled and countersunk. The shim(s) will dictate the final length of the six $\frac{1}{4}$"FH bolts. To allow the platform to vibrate freely, attach a spongy material under the front of the platform and a "rocker" (knife-edge) near the rear. Cut out a piece of 1" or so thick packing foam, 3" x 8", and glue it (Elmer's) to the bottom; add more thickness if necessary. Make a V-shaped stick, 8" long, and nail (glue?) it to the bottom as the "rocker". (Lots of alternatives here.) Assemble everything without the blades attached. Lock the drill's trigger in the "full on" position and place the platform on the edge of a table with the test blade(s) totally free to vibrate. Plug the drill's power cord into the Variac which is totally "off".

See the diagram for blade placement on the platform. Choose three $\frac{1}{2}$" x 10" hacksaw blades of the same make. Two 9/64" passing holes for the 5/8" x #6 panhead sheet metal screws are required on one end of each blade to fasten it to the platform; the holes should be 1" apart. See the diagram for the lengths that resonated best for my drill speed. Also, I bent about 5/8" of the tips downward about 45° and painted them for better visibility. Start with the longest blade first to get it to resonate at a low speed or frequency; don't expect much amplitude. Experiment by cutting the blade shorter to reach a satisfactory freq. For the second blade, cut it down $1\frac{1}{4}$" and test it. For the third blade, reduce its length another $1\frac{1}{4}$". I was able to shorten my blade lengths by $1\frac{1}{2}$" each. If you have extra blades to play with, you can try the $1\frac{1}{2}$" formula. Remember, the drill's rpm rating (range) determines the best blade lengths. Don't hesitate to change the dimensions of anything to get better results; adjustments may be required. The info here is but a place for you to get started; experiment as you wish.

Presentation: I painted the platform a bright green, the blades black, and their bent tips a bright yellow to be highly visible. To start the demo, pluck each blade to display its natural frequency, the longest (lowest freq.), the medium length, and the shortest (highest freq.). Slowly turn up the Variac until the longest blade reaches its best (natural) resonance point. Then turn up the Variac even higher; note that the longest blade slows down and goes out of resonance. Instead, the medium-length blade starts to vibrate. As the Variac is turned up higher, the medium blade reaches its best (natural) resonance point; the other two blades are relatively "quiet". Note, however, the large increase in amplitude (energy). That's because the Variac has been increasing both the voltage and the amperage to the drill ($P = VI$). Continue the process for the shortest blade and go slightly beyond, if possible, to "tune out". I've always found that the results are even better when I turn the Variac down, going easily through all three resonance points. Thus, your students should understand resonance much better now. Today, people say, "We're on the same page." In post WWII, people said, "We're on the same wavelength or frequency." Resonance is being in sync or to synchronize perfectly (to understand perfectly). Resonance has much meaning in many situations.

Diagram:



Addendum: Now that you have a good vibrating platform, you can extend its use to replicating a quality shaker table I first saw at N.Y.U. in the 1960's. It was probably used to study resonance and standing waves in skyscrapers during earthquakes.

To study vertical standing waves, simply replace the hacksaw blades with different lengths of strap steel from container shipments. See illustration (a) for the sizes of these strap steel "vibrators" that worked best for me. Again, you will have to experiment with their lengths depend-on their stiffness and the drill's range of rpms.

To study standing waves in a circle (hoop), attach a small bandsaw blade (hoop) as in illustration (b); mine is a ½" x 44 7/8" Porta Band saw blade by Porter Cable. This demo provides a striking simulation of the standing waves of electron orbits in atoms.

Presentation: In each case, slowly turn up the Variac until the desired effect is reached; repeat each effect coming back down. A screen behind (a) and (b) will enhance the effects considerably. A bright strobe light may be used to study the effects even further and provides a beautiful sight to behold.

Illustration: (a) vertical standing waves (b) standing waves in a circle (hoop)