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The Iowa wave machines

Tom Greenslade
Kenyon College, greenslade@kenyon.edu

John D. Daffron

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John D. Daffron, Thomas B. Greenslade Jr., and Dale Stille

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Wave machines are a staple of demonstration lectures, and a good pair of wave machines can make the idea of transverse and longitudinal waves clearly evident to students. The demonstration apparatus collection of the University of Iowa contains examples of transverse and longitudinal wave machines that will be of interest to readers of The Physics Teacher. These machines probably date from about 1925 and may have been locally produced. You too can build them.

The transverse wave machine in Fig. 1 is relatively straightforward and based on recognized 19th-century designs. A series of wooden cams is placed on a rotating shaft, each turned a certain fraction of a circle from its neighbor. Lengths of springy wire, bearing white disks on their ends, bear upon the cams and trace out a sinusoid. When the set of cams is rotated, the individual wires and disks move up and down in simple harmonic motion, and the wave shape moves to the right or left, depending on the direction of rotation.

The cam arrangement (Fig. 2) is the hardest part to construct, and details, suitable for the amateur builder, are given in the appendix. Briefly, the cams are slices from a wooden dowel that are assembled on a shaft. Each one is rotated at an angle of 45° to its neighbors, thus giving a complete cycle every eight cams.

Wooden balls, bought at a craft shop, are placed on the ends of spring steel wires that are inserted into a block behind the cams. The ends of the shaft holding the set of cams run in L-shaped mending plates screwed to the wooden base, and a crank like the one in Fig. 1 is attached to drive the machine.

Longitudinal wave machines are somewhat trickier to design and build. The up-and-down motion produced by the set of rotating cams must be translated into side-to-side harmonic motion. The overall view of the Iowa longitudinal wave machine is shown in Fig. 3. To understand the motion of the wire holding the oscillating disk, look at the mock-up in Fig. 4 that shows the wire constrained between two diagonal sets of slits at right angles to each other. When the wire is lifted up and down it moves from side to side. The role of the rotating cam is to produce this up and down motion; since it is harmonic, the side to side motion is harmonic. The horizontal slit at one end of the wire in Fig. 4 constrains any vertical motion of the wire at that end, and the spring (or rubber band) at the other end keeps the wire firmly pressed against the cam.

The construction of these wave machines is well within the capabilities of high school students.

Fig. 1. Transverse wave machine in the Iowa Collection. Photograph by Dale Stille.

Fig. 2. Camshaft for both the longitudinal and transverse machines. Construction and photograph by John Daffron.

Fig. 3. Longitudinal wave machine in the Iowa Collection. Photograph by Dale Stille.

Fig. 4. The operating mechanism for the longitudinal machine. Construction and photograph by John Daffron.
apparatus

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sonite™ with small nails.

On the first cam, mark the center of rotation, which in this case is about halfway between the edge and the center of the cam. Using this point as a center, scribe a circular arc of ½-in radius across the face of the cam, and with the aid of a protractor mark two points on the arc that are 45° apart. These points mark the positions of the pins (short lengths of coat hanger wire) that are used to phase the cams 45° apart. Using a drill press, drill holes for the pins, passing through the cam and Masonite and into the scrap wood beneath. The hole for the shaft should give a snug fit onto the threaded rod; to prevent tear-out either use a Forstner bit or hold the assembly tight to the scrap wood.

Now you can drill the rest of the cams. Clamp each one in place, turn the jig over, and use the holes that you have already drilled in the Masonite as guides.

To assemble the camshaft, insert a pin into the right hole of each cam, and slide the cams onto the shaft with the pins all facing in the same direction. Insert the projecting pin into the vacant hole in the adjoining cam, push all of the cams together, and use washers and hex nuts on either side of the collection of cams to hold them in place.

Reference

Appendix

Making the series of cams is the hardest part. Figure 2 shows a finished cam shaft, with all of the cams assembled on a threaded steel rod with nuts holding the collection together. The cams in the picture were cut from 1¼-in hardwood dowel using a miter box and saw.

The jig used for making the individual cams is shown in Fig. 5. The V-block is made from a piece of 1-x-2-in pine board, and diagonals marked across it serve as guides for cutting the V. The block is then secured to a thin base of Masonite™ with small nails.

Fig. 5. The jig used to make the cams. Construction and photograph by John Daffron.

Fermi Questions

Question 1: Liquid costs

What are the relative costs (per liter) of different liquids? Consider bottled water, gasoline, crude oil, perfume, vodka, and inkjet printer ink.

(Thanks to Dan Meyer in Santa Cruz, CA for inspiring the question.)

Question 2: Peeing before flying

All Nippon Airways recently (October 2009) started asking passengers to urinate before boarding the airplane. How much fuel would airlines save if passengers did this?

Look for the answers online at www.aapt.org/tpt. For more Fermi questions and answers, see Guesstimation: Solving the World’s Problems on the Back of a Cocktail Napkin, by Lawrence Weinstein and John Adam (Princeton University Press, 2008), available from AAPT.

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Larry Weinstein, Column Editor
Old Dominion University, Norfolk, VA 23529; weinstein@odu.edu.