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Apparatus for demonstrating longitudinal wave pulses

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Apparatus for demonstrating longitudinal wave pulses

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For live classroom demonstrations there are a number of devices that have been used to simulate waves. Some are based upon a design produced by E. S. Ritchie & Sons[1] and consist of rods and cams that are activated by turning a crank.[2,3] These devices show what transverse and longitudinal waves look like, but they do not allow for the free manipulation of wave parameters and observations of the changes that take place. A simple device can be constructed using elastic bands and straws[4] to demonstrate properties of transverse waves.

To demonstrate the properties of longitudinal waves, you can utilize devices that use springs. You can use a Slinky™ or springs on air tracks[5] or springs and rods.[6] The last two require significant construction time and skill.

Here we describe a simple device using magnets to demonstrate longitudinal wave pulses. It's not necessarily better than other devices, but it is easily and quickly made.

Material list

- 15-20 fender washers (1¼-in o.d. x ¼-in i.d.)
- Twice as many thick rare-earth neodymium magnet rings as washers (1/2-in o.d. x 9/32-in i.d. x 1/8 in)[7]
- One solid carbon fiber rod (¼-in diameter, 48 in long)[8]
- 15 minutes of spare time

Get the inexpensive zinc-plated steel washers from the local hardware or home improvement store, not the expensive stainless steel ones.

Assembly

Center a magnet on each side of the flat washer keeping the holes concentric and with opposite poles toward the washer, as shown in Fig. 1.

Slide the washer/magnet "particles" onto the carbon fiber rod, reversing the polarity as you go so that the "particles" repel each other, as in Fig. 2. That's it.

The hard carbon fiber rod and the hard neodymium magnets have a small coefficient of kinetic friction as compared to the same magnets on a wooden dowel. The friction damping can be further reduced by applying a silicone lubricant spray to the rod.

Using the apparatus

To use the apparatus, hold the rod horizontally from each end and jiggle it a bit so that the "particles" space themselves equally about 1½ to 2 inches along the rod. Hold the rod securely with one hand close to the end "particle." With the index finger of your other hand on top of the rod and your middle finger below the rod, as in Fig. 3, give the washer at the end a quick slap, sending it sliding into the other "particles." You can easily see the pulse travel down the rod and reflect from your hand on the other end. It won't take long to determine the correct slap speed.

Variations

The fender washers can be replaced with circles cut from card stock, which would make it more visible from a distance, or you could use CDs or DVDs with the magnets attached to ¾-in o.d. washers that are epoxied concentrically on one or both sides of the disk. Here is another use for your dud CD/DVD-burning attempts. The advantage of using the washers

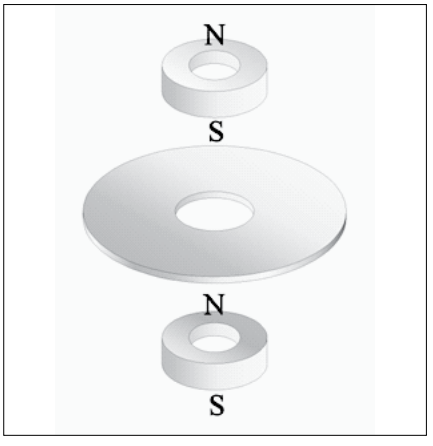

Fig. 1. Assembly of the fender washer and magnets.

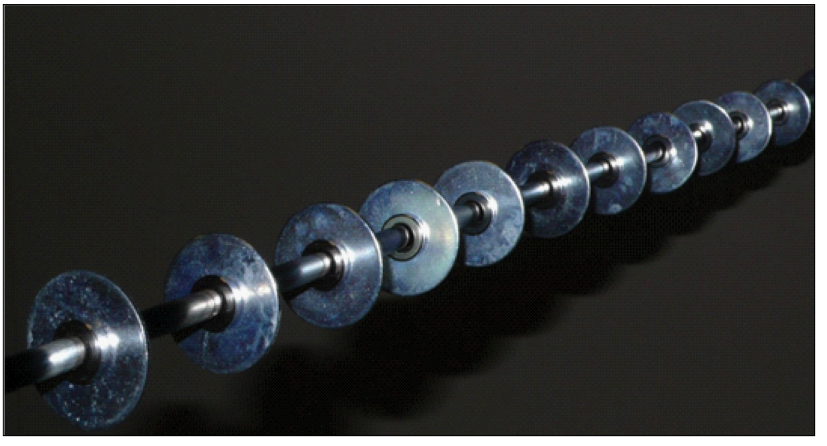

Fig. 2. Magnet-washer-magnet "particles" on the carbon fiber rod.

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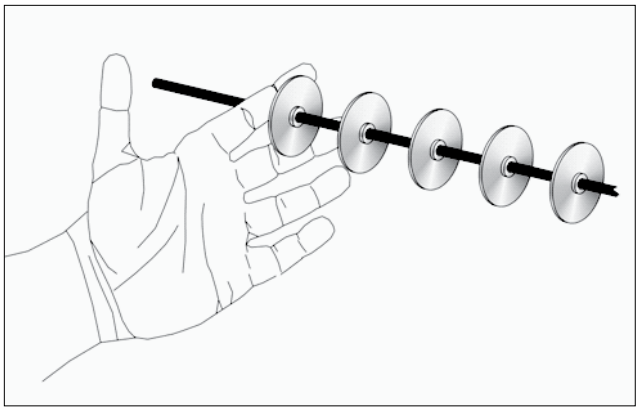

Fig. 3. Initiating a longitudinal pulse.

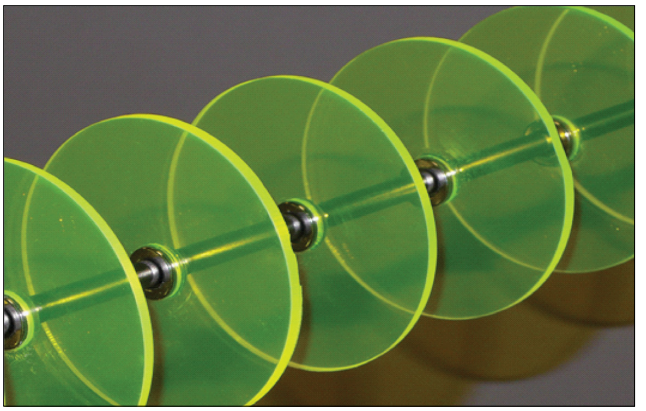

Fig. 4. Fluorescent disk model of the longitudinal wave apparatus.

or card stock is that the apparatus can be disassembled and the magnets used for other purposes.

Figure 4 is an example of a permanent version of this apparatus for use in a large classroom. This variation was constructed from 3⅞-in. diameter circles of 1/8-in fluorescent acrylic with a 0.500-in hole reamed in the center. The circles were laser cut at a local engraving shop. Two magnets were pressed into the hole and glued in place with cyanoacrylate adhesive (Super Glue®).

Conclusion

Although there are a number of devices available to demonstrate longitudinal waves, the device that we describe here is unique because it has the attributes of being inexpensive, easy to construct, and can be made to be highly visible in the classroom.

References

1. E. S. Ritchie & Sons, Inc., *Illustrated Catalogue of Philosophical Instruments, and School Apparatus* (Boston, 1860).
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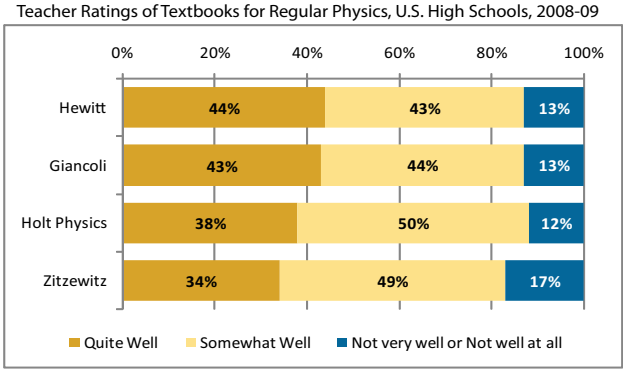
5. *Physics Demonstration Experiments, Volume 1: Mechanics and Wave Motion*, edited by Harry F. Meiners (The Ronald Press Co., New York) pp. 260-261.
6. Akio Saitoh, "New longitudinal waves demonstrator," *Phys. Educ.* **19**, 29–30 (1984).
7. The magnets are Model# NR008-1 from www.magnet4less.com.
8. The carbon fiber rod is Product #020078 available at www.goodwinds.com.

Teacher Reviews of Widely Used Physics Textbooks

Holt Physics (Serway & Faughn), *Physics Principles and Problems* (Zitzewitz), *Conceptual Physics* (Hewitt), and *Physics: Principles with Applications* (Giancoli) were the most widely used textbooks for regular high school physics courses during the 2008-09 academic year. *Holt Physics* and Zitzewitz were each used by about one-third of the teachers responding to our Nationwide Survey of High School Physics Teachers. Hewitt's text was used by approximately one-fourth of the teachers who responded, and 6% of the respondents reported using Giancoli. We also asked the respondents to tell us how well the text worked for the course. The good news is that well over 80% of the teachers find that all four of these texts work quite well or somewhat well for teaching regular physics.

Teacher Ratings of Textbooks for Regular Physics, U.S. High Schools, 2008-09



Ratings are based on a four-point scale: Quite well, Somewhat well, Not very well, Not well at all
Differences less than 5% are not statistically significant.
www.aip.org/statistics

We describe the usage and teacher ratings for texts for conceptual physics, honors physics, and both AP physics classes in the full report, "Focus on High School Physics Textbooks," which is available for download at http://www.aip.org/statistics/trends/hstrends.html.

Next fall, we will look at women and minorities in high school physics. If you have any questions or comments, please contact Susan White at swhite@aip.org. Susan is Research Manager in the Statistical Research Center at the American Institute of Physics and directs the high school survey.

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