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Build Your Own Soliton Generator

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The concept of a "solitary wave" was first introduced in 1844 by the British engineer J. S. Russell to characterize his observation of a localized mass of water propagating along a narrow canal without changing its form or speed.

The term "soliton" was used in 1965 by N. J. Zabusky and M. D. Kruskal to describe a numerically simulated interaction of propagating solitary waves that kept their own identities after emerging from a collision (without changing their forms or speed), analogous to elastic interactions of particles.

The phrase "nonpropagating hydrodynamic soliton" was employed in 1983 by S. J. Putterman to characterize the discovery of a localized pulse in a water trough (a rectangular waveguide parametrically excited) by I. Rudnick at UCLA. This soliton was fundamentally different from other propagating solitons observed before—it remained stationary along the length of a water trough while sloshing back and forth across the width of the same trough. The nonpropagating soliton is robust and stable within a range of frequencies and amplitudes of the drive. Many research papers and a couple of Ph.D. theses have been written on the subject since its discovery.[1-5] Recent work in the theory and experiments of this soliton can be found in the literature.[6-7]

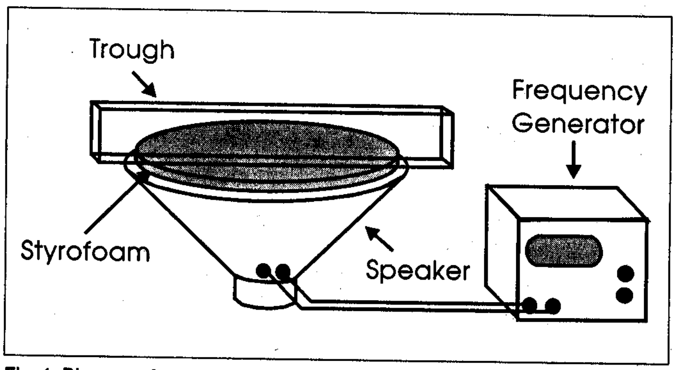

Fig. 1. Diagram of set-up.

The nonpropagating hydrodynamic soliton draws immediate wonder from everyone who sees it. As we will show here, it is a simple matter to build a soliton generator, an apparatus that will soon become an indispensable part of any high-school or college collection. Although the idea is not new, the low cost is attractive. With a simple frequency generator,[8] a little work and time, and $50 or so, anyone can construct a setup to demonstrate this extraordinary phenomenon.

The user can go back and forth from the nonpropagating hydrodynamic soliton to ordinary standing waves to show a self-focusing phenomenon resulting from the balance of dispersion and nonlinearity. This demonstration can be used by instructors discussing topics on waves, parametric excitation, resonance, nonlinearity, and dispersion.

Materials Needed:

- 12-in 40-W woofer
- Petroleum jelly
- Styrofoam (¼-in to 1-in thick) large enough to cover speaker
- Foam sealant (e.g., Polycel expanding foam used to fill holes and cracks)
- Food coloring
- Kodak Photo-Flo 200 chemical
- Plexiglas or glass trough (channel) with inner dimensions 38 cm long, 2.6 cm wide, 7 cm high
- Frequency generator and voltmeter
- Index cards (3 x 5 size)

Construction of Snake Table

– Smear the inside of the speaker with petroleum jelly, brushing

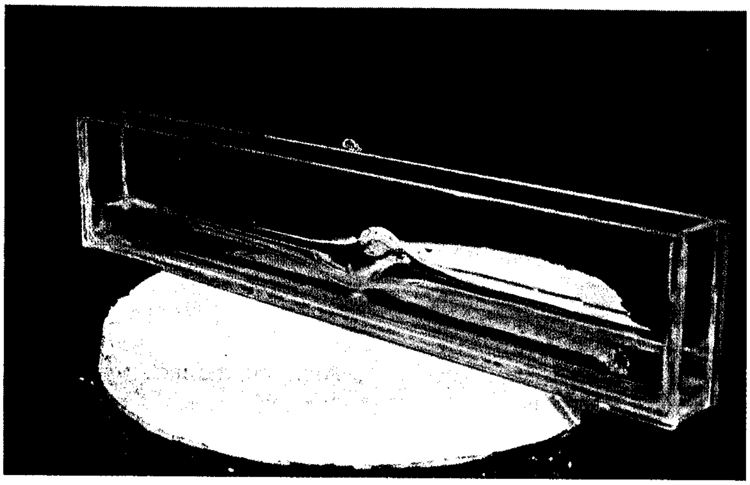

Fig. 2. Soliton generator in operation.

the jelly to a thin coat that covers the entire speaker (including its borders).

- Cut a hole (approximately 2-cm diameter) in the center of the Styrofoam.
- Fill the speaker about half full with the expanding foam and cover the speaker with the Styrofoam, which should rest evenly across the top of the speaker.
- Wait three to four hours as the foam expands. You will see a small amount of foam protruding from the hole.
- Cut off this excess bulb of foam so that the surface is completely smooth. Also trim the Styrofoam around to fit the edges of the speaker.

Experiment

- Place the glass trough (constructed to dimensions) on the shake table. Add water in the trough to a depth of exactly 2 cm.
- Add approximately 10 ml of food coloring (about half a capful) to the water to make the wave easier to see.
- Next add approximately 40 ml of the photo chemical. This decreases the surface tension. Gently stir the solution until the coloring is even throughout.
- Attach the speaker to the frequency generator, and also attach a voltmeter across the generator. The rms output should be somewhere between 0.4 and 0.5 V.
- Place two dampers (made from folded index cards) into the trough about 3 cm in from the ends. These dampers should stop undesired waves.
- Set the frequency at 10.4 Hz. Standing waves should form moving in the long direction of the trough.
- Remove any bubbles that may have formed in the calm middle portion.
- Tilt the trough backwards (about 45 degrees) to eliminate standing waves and quickly allow the trough to rock back. This should generate waves moving in the width dimension. These waves should quickly form into the soliton.
- After the soliton is formed, lower the frequency to around 10.2 Hz and gently remove the dampers.

Remarks

While the trough is oscillating up and down, only a small portion of the water pulsates up and down. The rest of the water trough remains flat. The soliton is localized along the length of the trough, while sloshing back and forth across the trough. It is about 5 to 6 cm in length. The cross section of the soliton matches a hyperbolic secant profile.[7] Peering at it from above, it will look like a small pool in the middle of the water, with its edges extended up the sides of the trough. From a side angle it will appear as a steady series of small triangle-shaped splashes against the edge of the trough (see picture). The soliton will continue indefinitely. It is possible to reposition the soliton by gently blowing on it sideways.

Acknowledgment

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