Pendulum Waves

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What it shows : Fifteen uncoupled simple pendulums of monotonically increasing lengths dance together to produce visual traveling waves, standing waves, beating, and random motion. One might call this kinetic art and the choreography of the dance of the pendulums is stunning ! Aliasing and quantum revival can also be shown.

How it works : The period of one complete cycle of the dance is 60 seconds. The length of the longest pendulum has been adjusted so that it executes 51 oscillations in this 60 second period. The length of each successive shorter pendulum is carefully adjusted so that it executes one additional oscillation in this period. Thus, the 15th pendulum (shortest) undergoes 65 oscillations. When all 15 pendulums are started together, they quickly fall out of sync—their relative phases continuously change because of their different periods of oscillation. However, after 60 seconds they will all have executed an integral number of oscillations and be back in sync again at that instant, ready to repeat the dance.

Setting it up : The pendulum waves are best viewed from above or down the length of the apparatus. Video projection is a must for a large lecture hall audience. You can play the video below to see the apparatus in action. One instance of interest to note is at 30 seconds (halfway through the cycle), when half of the pendulums are at one amplitude maximum and the other half are at the opposite amplitude maximum.

Comments : Our apparatus was built from a design published by Richard Ber [1] at the University of Maryland. He claims their version is copied from one at Moscow State University. Dr. Jiri Drabek at Palacky University in the Czech Republic has informed us that it was originally designed and constructed by Ernst Mach, professor of mathematics in Praha and Vienna around the year 1867. The demonstration is used in the Czech Republic under the name Machuv vinostroj—the « Wavemachine of Mach. » The apparatus we have was designed and built by Nils Sorensen.

James Flaten and Kevin Parendo [2] have mathematically modeled the collective motions of the pendula with a continuous function. The function does not cycle in time and they show that the various patterns arise from aliasing of this function—the patterns are a manifestation of spatial aliasing (as opposed to temporal). Indeed, if you've ever used a digital scope to observe a sinusoidal signal, you have probably seen some of these patterns on the screen when the time scale was not set appropriately.

Here at Harvard, Prof Eric Heller has suggested that the demonstration could be used to simulate quantum revival. So here you have quantum revival versus classical periodicity !

Ce texte et la vidéo qui l'accompagne sont tirés de « Harvard Natural Sciences Lecture Demonstrations » en ligne ici. Ils nous ont été obligeamment signalés par Jean-Paul Vignal.

Notes

[1] *Am J Phys* 59(2), 186-187 (1991).

[2] *Am J Phys* 69(7), 778-782 (2001).