ALPhA Advanced Laboratories

ALPhA's Laboratory Immersions

Mechanical Chaotic Oscillator

California State University at Chico, July 17–19, 2017.

(Space for up to seven participants)

Host and Mentor

Eric Ayars (B.S. Pacific Union College; Ph.D. North Carolina State University) is Professor of Physics at California State University at Chico. He writes: "My senior thesis as an undergraduate physics major was on this exact system, but back in the dark ages computers couldn't track this much data, DAC's couldn't generate signals this precisely, and devices like the Teensy 3.1 microcontroller board and benchtop laser cutters were pure science fiction. I love designing and building new instruments for teaching physics, and really enjoy sharing ideas with fellow teachers."

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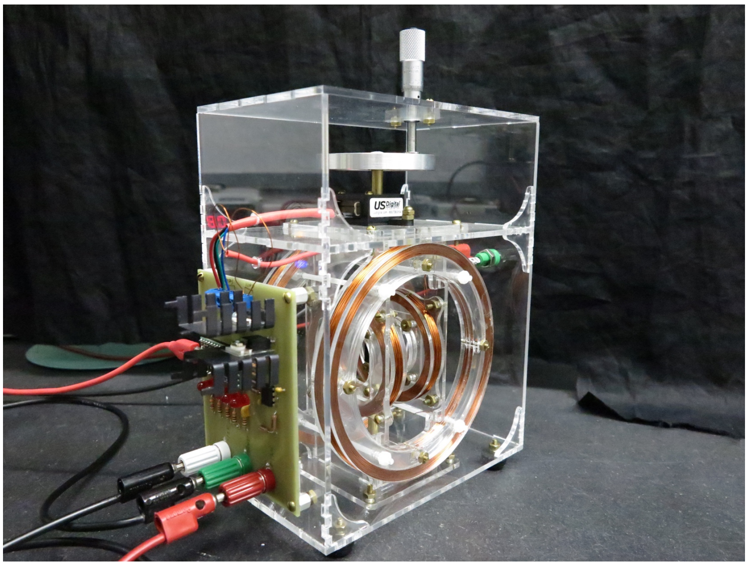
The rotation of a magnetic dipole in an oscillating magnetic field varies from stable oscillations to chaotic motion, depending on the system parameters. The Mechanical Chaotic Oscillator developed at CSU-Chico allows complete control of all system parameters, and can be used for high-resolution studies of chaotic motion, phase space diagrams, Poincaré plots, and observations of bifurcations on the path to chaos. This particular chaotic system is analogous to a circular pendulum with an oscillating horizontal component of gravitational force.



The apparatus is smaller than a breadbox, connects to a standard USB port for data collection and instrument control, and uses no special lab equipment or dedicated computer hardware. It is controlled by a Teensy™ microcontroller which synthesizes the drive signal and tracks position and velocity of the rotor. (Click on photo for a higher resolution view.)

Chaos is a subject of considerable interest; this apparatus allows students to investigate it with full control of damping, drive amplitude and frequency, and central restoring force. The apparatus synthesizes the drive component of field and provides high resolution angle and angular-velocity data at 256 steps per drive cycle. This data allows for easy construction of Poincaré plots and even movies showing how the Poincaré plot evolves over the course of a drive cycle.

Student skills gained by using this apparatus include computer analysis of large data sets, SCPI instrument communications, and hopefully a better understanding of chaotic systems. Immersion participants will gain experience in lasercutting parts, designing custom boards, microcontroller programing, and equipment design. Participants will also build their own apparatus to take home.

Tasks include cutting parts, building and winding coils, electronics assembly and soldering, and firmware flashing. Once the apparatus is constructed (1.5–2 days) participants will program computers (in Python, LabVIEW, or both) to control the experiment and obtain sample data. (1–1.5 days)

Participants should bring their lab notebook and a flash drive. Laptops are optional; participants may find it useful to get things working on their own computers, although computers will be provided here also.

There are no safety concerns, other than the usual hazards associated with soldering, solvent-welding, and using a lathe.

The apparatus can be built for less than $300, if the necessary tools (i.e. laser cutter) are available at the home institution. (Participants will of course keep the one they build during this Immersion.)

Please note that the Jonathan F. Reichert Foundation has just established a grant program (ALPhA webpage; Foundation website) to help purchase apparatus used in Laboratory Immersions. Limitations and exlusions apply, but generally speaking the foundation may support up to 40% of the cost of the required equipment.