Forecast:

And the Winner is...

The Relaxation Times

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VOL. IV No. 2 ***NEWSLETTER OF TEACHSPIN, INC.*** ***Feb. 2013***

It's Time to Update Your CV, Photograph Your Advanced Lab,

AND nominate yourself and/or your colleague for the

Jonathan Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction

Yes, after a year of negotiations, the APS has finally created a prize that brings long overdue recognition to this essential component of physics education. We here at TeachSpin have always realized the extremely important and difficult work that goes into creating and maintaining a modern, well equipped, multi-semester, and challenging junior/senior advanced laboratory program. We are also convinced that such programs are a critical component of an undergraduate physics education. By establishing this permanent award, the APS now has tacitly agreed with our assessment.

The award was approved by the APS on November 3, 2012 and the first award will be given at the 2014 APS March Meeting in Denver, Colorado. Barbara and I will be there to personally honor the first recipients. The award consists of $5,000 in cash, a plaque for the lab, and all expenses paid to attend the Denver meeting. The honoree is 'obligated' to give an invited presentation describing the award winning laboratory program.

Now, I know that physicists are, generally speaking, loath to shine a spotlight on themselves. But it is time to GET OVER IT! We know personally many of you who should be on the long list of potential recipients. Get over your shyness, read the rules which are on the APS website, and apply. The nomination list should be a long one for the committee to ponder. Barbara and I are just too busy to write a letter for each and every one of the people who deserve this award and it might appear like a conflict of interest if we did! Now, it is up to you.

APS physics

Awards, Medals & Lectureships

David Adler Lectureship Award in the Field of Materials Physics
Edward A. Bouchet Award
Excellence in Physics Education Award
Francis M. Pipkin Award
George E. Duvall Shock Compression Science Award
Henry Primakoff Award for Early-Career Particle Physics
John Dawson Award for Excellence in Plasma Physics Research
John H. Dillon Medal
John Wheatley Award
Jonathan Reichert and Barbara Wolff-Reichert Award for Excellence in Advanced Laboratory Instruction
Joseph A. Burton Forum Award
Joseph F. Keithley Award For Advances in Measurement Science
Landau-Spitzer Award
LeRoy Apker Award
Leo Szilard Lectureship Award
Maria Goeppert Mayer Award
Nicholson Medal for Human Outreach
Otto Laporte Award (last awarded in 2003)
Stanley Corrsin Award

We want to thank the many people who wrote to the various committees of the APS supporting the creation of this award. In my judgment, the letters made the difference. Those letters of support showed the breadth and depth of concern of the faculty for this part of undergraduate instruction that has, for far too long, been devalued. This award will not revolutionize the academic culture, but it has a good chance to modify it. That will be especially true if the selection committee is faced with 25 – 30 outstanding nominations not only this year, but every year. We have watched the effort expended and seen the passion and commitment advanced lab instructors must have to create meaningful experiences for their students. The time has come for that generosity of spirit to be honored. –JFR

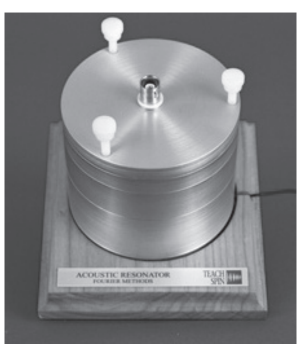
Students Should Master Fourier Methods

TeachSpin's collaboration with Stanford Research Systems gives your school a unique opportunity that should not be passed up. You can purchase, through TeachSpin, SRS's high performance spectrum analyzer, the SR770, along with an extensive collection of TeachSpin designed apparatus (called the 'Physics Package') and a self-paced physics curriculum manual, for a few hundred dollars more than it would cost you to purchase the SR770 directly from SRS. We are able to do this because SRS has generously offered to support physics education and has made these remarkable units available to schools, through TeachSpin, at their cost of parts and labor. Both SRS and TeachSpin believe it is extremely important that the next generation of experimental physicists be at least literate, if not expert, in the use of spectrum analyzers.

What electronic experimental 'tools' do we expect all physics majors to master before they graduate. The **multimeter, oscilloscope,** and **lock-in amplifier** are the first that come to mind. Both TeachSpin and SRS believe that list must also include a **spectrum analyzer.** This technology has become so sophisticated and available that we are derelict in our duty as educators if we do not require our students to learn these techniques. ***Simply put, Fourier Methods belongs in the cannon of undergraduate physics education.***

There are so many experiments and 'exercises' in TeachSpin's "Fourier Methods Physics Package" that we can only highlight a few in this issue: **Acoustic Resonator, Coupled Oscillators** and **Fluxgate Magnetometer.**

Acoustic Resonator



The Acoustic Resonator is a variable height cylindrical structure equipped with a miniature speaker (for excitation) and an electrostatic miniature microphone (for pickup).

It is, of course, possible to find the acoustic normal modes or resonant frequencies of this system the old-fashioned way. That is, by driving the speaker with a sine-wave generator and monitoring the microphone signal. Then, each normal mode should be detected in succession as a resonant enhancement of the microphone signal. However, for such a high-Q resonator, with many narrow resonances, the process is tedious and risks missing resonances by scanning too fast.

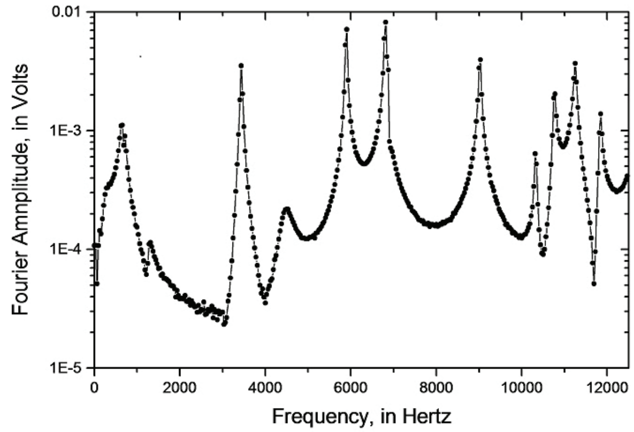


Figure 1: Acoustic Resonances

Fourier Methods has what is known as the 'Fellgett advantage' for this kind of measurement. Instead of driving the speaker with a monochromatic signal, the SR770 produces a *white-noise* output signal, which acts like a superposition of all frequencies at once, to excite the speaker. The microphone picks up all of these frequencies, but the *resonant* frequencies are enhanced. If you examine these pick-up signals on an oscilloscope (time-domain), they would appear messy and barely intelligible. However, the Fourier spectrum of the signal, shown in Figure 1, clearly shows the whole panoply of cavity resonances emerging in parallel, *all at once.*

Coupled Oscillator

Another experiment included in the Fourier-Method package is an electro-mechanical Coupled-Oscillator apparatus. This has two chief mechanical degrees of freedom: the individual torsional motions of two phosphor-bronze reeds. A permanent magnet is mounted on the tip of each reed so the motion of either reed can be excited, or detected, via its own drive-pick-up coil. But the two magnets also interact by direct dipole-dipole coupling, so the *coupled* system displays two normal modes of oscillation.

These two modes of oscillation could, of course, be found by traditional monochromatic excitation and a sweep search, but given the resonant frequencies near 150 Hz and Q-values over 300, such a search is painstaking. Instead, the SR770 can excite the system by a deterministic version of noise call '*chirp*'. (For 'ordinary' noise the signal amplitudes vary randomly. In 'chirp' noise the amplitude of the noise signal is the same for every frequency in the selected range. This means the variation of amplitude in detected signal is due only to resonance effects.) Again, the Fourier analysis of the result shows the response of the system to a whole band of frequencies, all acquired in parallel.

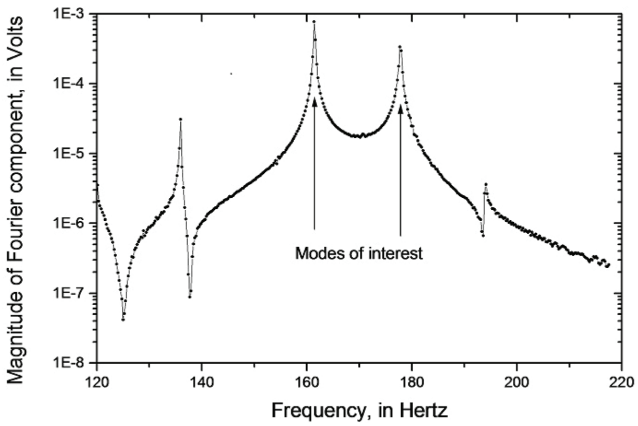


Figure 2: Coupled Oscillator Chirp Signal

A plot of the response of the system as a function of frequency, excited at one coil, and detected at the other coil as pick-up, is shown in Figure 2. The two normal modes show up as the main peaks in this spectrum, and the semi-log display shows off the huge dynamic range the SR770 offers. Spectra such as this allow both of the normal-mode frequencies to be read to < 0.1 Hz uncertainty.

This coupled oscillator includes a magnetic 'tuning' coil that permits a non-contact and real-time way to separately fine-tune the two reed-oscillators torsional resonant frequencies. While two non-interacting oscillators would yield resonant frequencies that crossed as a function of the tuning coil's magnetic field, the two coupled oscillators instead display the lovely '*avoided crossing*' of normal-mode frequencies show in Figure 3.

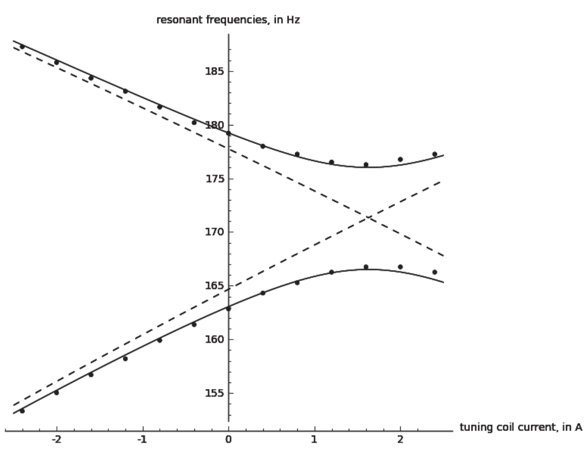


Figure 3: Coupled Oscillators 'avoided crossing'

Fluxgate Magnetometer

A fluxgate magnetometer is a device for measuring magnetic field strength based on the non-linear properties of ferromagnetic materials. Among the many technologies that can be used to measure magnetic fields, the fluxgate method is distinguished by its high sensitivity, fast response, low power consumption, and its simplicity. It is also a good example of an instrument whose analysis is enhanced by Fourier analysis. Space does not permit a comprehensive exploration of the fluxgate, but for this exposition, it is sufficient to understand that its ferromagnetic elements are driven with an ac magnetic field into regions of saturation. The output signal from a secondary coil, whose emf is governed by Faraday's Law, contains the drive frequency and multiple harmonics. This output signal is Fourier analyzed by the SR770 and shown in Figure 4.

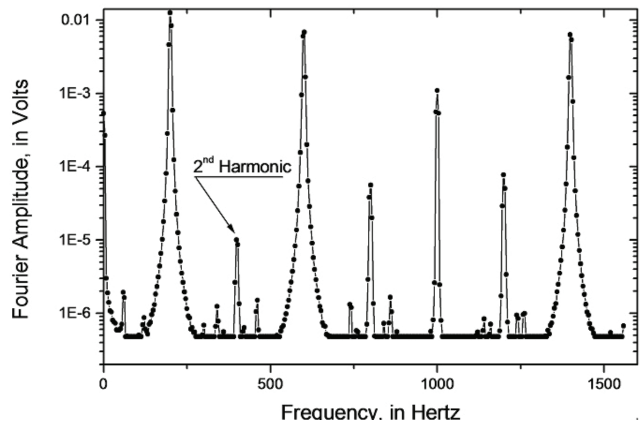


Figure 4: Output signal of the Fluxgate Magnetometer driver at 200 Hz in a zero magnetic field. The various harmonics are clearly visible at 400, 600 and 800 Hz.

What is not obvious is that the second harmonic signal is directly proportional to the external magnetic field at the ferromagnetic materials. In our case, we can apply a well-characterized magnetic field via the solenoid and calibrate the magnetometer. In Figure 5, we show the same spectrum, but this time with a 3 mT solenoid magnetic field. The SR770 allows accurate measurements of the amplitude of the second harmonic signal. This measurement can be used to directly calibrate the fluxgate.

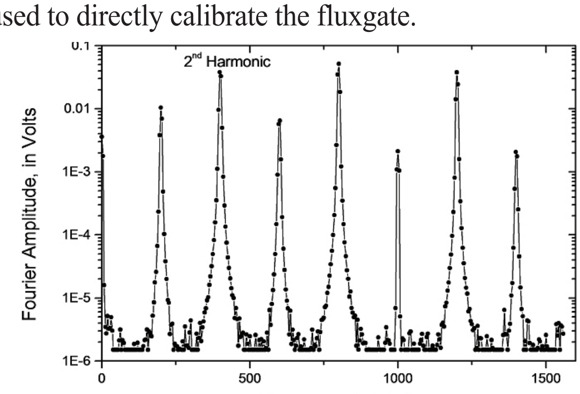


Figure 5: Output signal of the Fluxgate Magnetometer in a 3 mT magnetic field.

TEACH SPIN

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- *Quantized Conductance and the Arduino Platform for Advanced Labs*
- *Laser Induced Fluorescence in Iodine Molecules Molecular Spectroscopy*

June 26-28 Bethel University (MN)
- *Imaging Shock Waves in Compressible Flows*
- *External Cavity Diode Lasers & Spectroscopy*
- *Plasmonics and Surface-Enhanced Spectroscopy*

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