TEACH SPIN

SHORT FORM CATALOG No. 12

INSTRUMENTS DESIGNED FOR TEACHING

FOURIER METHODS

SR770 FOURIER ANALYZER
(Stanford Research Systems)

COUPLED MECHANICAL OSCILLATOR

ELECTRONIC MODULES
(Fifteen Functional Circuits)

FLUXGATE MAGNETOMETER

ACOUSTIC RESONATOR

- Learn frequency-domain analysis using a variety of frequency-space examples
- Use the unsurpassed frequency resolution, dynamic range, and versatility of the SR770
- Carry out experiments on modulation, demodulation, and signal recovery
- Execute three 'external experiments' reinforcing frequency-space methods
- Explore the comprehensive instruction manual covering curricular activities, projects and mathematics

NOISE FUNDAMENTALS

- Detect and quantify Johnson noise, the 'Brownian motion' of electrons
- Determine Boltzmann's constant, k_B, from temperature dependence of Johnson noise
- Observe and quantify shot noise to measure the fundamental charge '*e*'
- Configure front-end low-level electronics for a variety of measurements
- Investigate 'power spectral density' and 'voltage noise density' and their V^2/Hz and $V/\sqrt{Hz}$ units

PULSED/CW NMR SPECTROMETER

- Explore NMR for both hydrogen (at 21 MHz) and fluorine nuclei
- Magnetic field stabilized to 1 part in 2 million
- Homogenize magnetic field with electronic shim coils
- Research grade measurement of T_1 and T_2
- Compare CW and FID signals from both protons and fluorine
- Measure chemical shifts in inequivalent hydrogen and fluorine nuclei
- Observe PNMR/CW NMR in soft solids

The Hartshorn-coil structure, shown mounted on the dewar's baseplate, with the inner can removed.

We use lock-in detection to process the signals, and thereby also become sensitive to electrical conductivity (if any), in addition to sensing magnetic susceptibility. We provide a suite of *samples* with the experiment; and in addition, we empower students to create their own samples, using an epoxy-encapsulation technique.

SPECIFIC HEAT uses a vacuum heat-pulse calorimetry technique that measures the heat capacity of samples. Measurements using it will show, experimentally, that the classical Dulong-Petit claim of the temperature-independence of the specific heat, $c_p(T)$, is false. The motivation, of course, is the investigation of Einstein and Debye models for specific heat. The investigation thus shows the applicability of quantum-mechanical principles to the thermal behavior of macroscopic bodies. The technique is also directly sensitive to phase transitions, if any, in the sample.

7KHVSHFLFKHDWHSHULPHWMKUJDWWRDDRGKLWHDPSOH clipped to the 'addendum', suspended above the baseplate.

Here too, we provide a suite of *samples*, interesting for their temperature-dependent specific heat, and for various kinds of phase transitions. Again, our set-up will also accommodate student-created samples, either in solid or powder-in-epoxy form.

ELECTRONIC SUPPORT for these experiments, and for our dewar, is also part of our CMP development. Our vacuum system comes with the gauges required; our dewar comes with the temperature-stabilizing servo-mechanism, and the temperature-measuring transducers, that are required. We house the associated electronics in a Stanford Research Systems bin or 'rack' for SIMs (Small Instrument Modules), and we make use of modules both from TeachSpin and from SRS.

Stanford Research System's 'mainframe' for SIMs, populated with electronic modules from TeachSpin and SRS

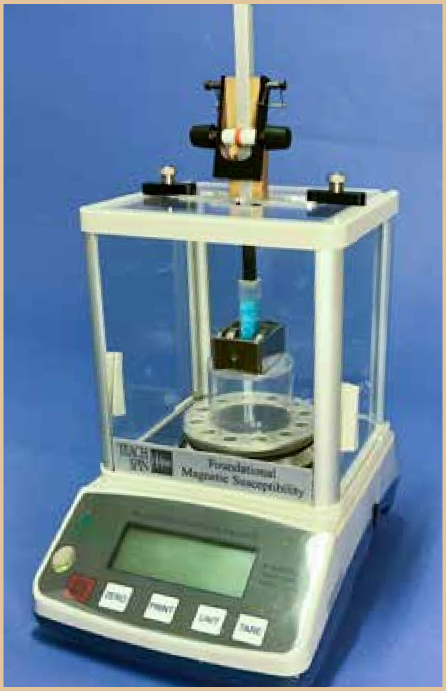
The SIM-bin also accommodates the proprietary electronic modules that come as parts of our individual experiments. Thus the low-level and custom analog electronics needed for the experiments you choose will arrive with your chosen apparatus.

SUMMARY:

On a well-thought-through 'platform' of a dewar optimized for use in the advanced lab, you can host, in turn, one of three experiments introducing your students to fundamental phenomena in condensed-matter physics. You might already have the vacuum system you'd need; you might start with just one of our three experiments on offer. See our website for details (and prices), and our collection of newsletters for samples (and sample data), to learn how TeachSpin hopes to address the under-representation of condensed-matter physics in the advanced lab.

Support electronics on optional TeachSpin shelving (at left) accompanies the CMP dewar (center) and recommended pumping system (at right) to EDVRUDPIRERQSDR meters of table space.

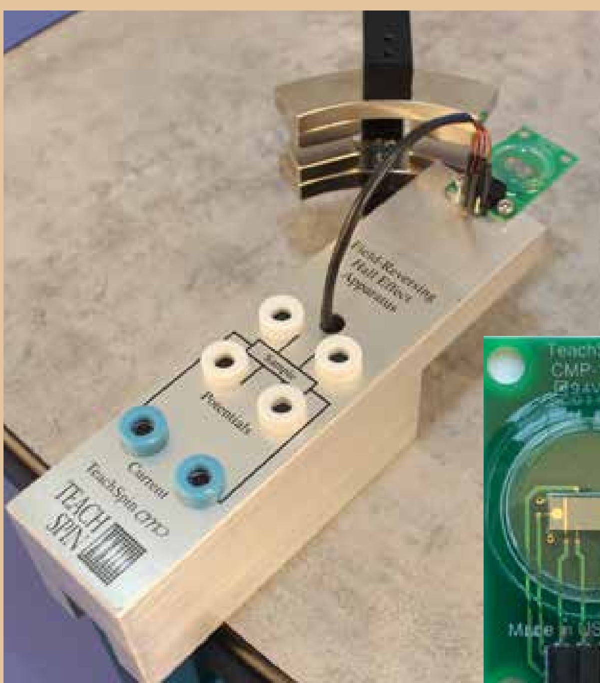
FOUNDATIONAL MAGNETIC SUSCEPTIBILITY



- Measure magnetic susceptibility of solids, liquids and powders
- Unambiguously distinguish dia- and para- magnetism
- Verify properties exclusively predicted by quantum mechanics
- Use first-principles calibration to get quantitative results
- Detect magnetic susceptibility of water with S/N ≈ 10/1
- Exploit Guoy method for straightforward and understandable data reduction

DEMYSTIFY & QUANTIFY DIA- & PARA-MAGNETISM

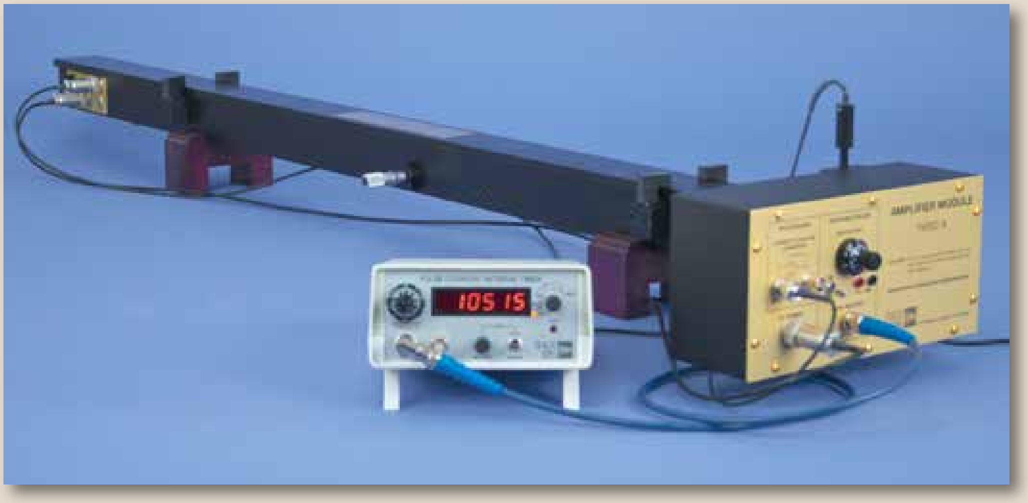
ROOM TEMPERATURE HALL EFFECT



- Optimized for demonstrating the Hall Effect
- Accommodates TeachSpin silicon and copper samples
- Permanent-magnet structure provides reversible *B*-field
- Transparent connections for tracking polarity
- Unambiguously gives *sign* of charge carriers, for n- and p-type Si *and* for Cu
- Permits 4-wire measurement of resistivity in semiconductors
- Comes with current-limiting resistor and current-reversing switch
- Guides students to first-principles measurements of sign and magnitude of *B*-field

DEMONSTRATE & MEASURE THE HALL EFFECT

TWO-SLIT INTERFERENCE, ONE PHOTON AT A TIME



- Recreate Young's two-slit measurement of the wave-length of light
- Perform two-slit interference with single-photon source and detector
- Investigate quantitatively the one-slit and two-slit interference patterns
- Learn the properties of photomultiplier tubes and pulse discriminator
- Use Counter's computer interface to investigate the statistical properties of photon events

OPTICAL PUMPING of RUBIDIUM VAPOR

- Optical pumping of rubidium atoms, Rb^{85} and Rb^{87}
- Explore magnetic hyperfine interactions of rubidium
- Observe zero-field transitions
- Confirm Breit-Rabi equation
- Observe double quantum transitions
- Study Rabi Oscillations
- Measure optical pumping times
- Study temperature dependence of experimental parameters

DIODE LASER SPECTROSCOPY

- Perform Doppler-free spectroscopy of rubidium vapor
- Use Michelson and Fabry-Perot interferometers for calibration
- Observe resonant Faraday rotation in Rb vapor
- Observe Coherent Population Trapping
- Measure temperature dependence of absorption and dispersion coefficients of Rb vapor
- Lock laser to rubidium hyperfine transition
- Study Zeeman splitting in Rb spectrum at two wavelengths
- Study stabilized diode laser characteristics

EARTH'S FIELD NMR with GRADIENT/FIELD COILS

- Observe the free-induction-decay signals from protons, fluorine, and other nuclei
- Discover Curie's Law and spin-lattice relaxation
- Cancel out local gradients to obtain long-lasting precession signals
- Use Helmholtz coils for absolute measurement of proton magnetic moment
- Create a one-dimensional magnetic resonance image (MRI)
- Generate (and hear!) audio-frequency 'spin echoes'
- Includes spin-flip coils for investigations of resonant excitation

TORSIONAL OSCILLATOR

- Experiments in Simple Harmonic Motion appropriate at all undergraduate levels
- Independently adjustable torsion constant, rotational inertia, and damping
- Precision analog angular-position and angular-velocity transducers
- Magnetic torque actuator permits arbitrary drive waveforms
- Eddy-current (v^1), sliding-friction (v^0), and fluid-friction (v^2) damping options

SIGNAL PROCESSOR/ LOCK-IN AMPLIFIER

- A teaching lock-in amplifier
- Multiple electronic strategies for processing electronic signals
- Built-in noise generator and test signals
- Follow the signal path
- Modular design

MODERN INTERFEROMETRY

- Build Michelson, Sagnac, and Mach-Zehnder interferometers
- Generate and count interference fringes manually or electronically
- Use 'quadrature Michelson' interferometry to count bi-directionally
- Perform experiments in thermal expansion, magnetostriction, index of refraction, and the electro-optic and piezoelectric effects
- Observe white-light interference and quantify optical coherence
- Measure thickness interferometrically with 80-nm resolution
- Includes two lasers, proprietary mirror mounts, up-down electronic counter, multiple detectors, etc. – everything you need for a course in interferometric measurements

MAGNETIC TORQUE

- Measure magnetic moment, μ, **FIVE** independent ways
- Observe classical analog of magnetic resonance
- Model nuclear precession and NMR spin-flip

FARADAY ROTATION

- Measure Verdet constant of transparent solids and liquids
- Study interaction of light, matter, and magnetic fields
- Use with Lock-in Amplifier to measure extremely small Verdet constants

QUANTUM ANALOGS

Acoustic models of:

- Hydrogen atom and hydrogen molecule
- Lowering symmetry to lift degeneracy
- Band gaps in semiconductors
- Impurity states in semiconductors

Thermodynamic measurement of:

- Velocity of sound in air and other gases
- Velocity of sound as a function of temperature

MAGNETIC FORCE

- Discover magnetic force depends on field gradient
- Measure μ from magnetic force

MUON PHYSICS

- Detect cosmic-ray Muon flux
- Measure lifetime of stopped Muons
- Demonstrate relativistic time dilation

COUNTER/TIMER

- True events per-unit-time counter
- Measure interval time with µs resolution
- Built-in pulse-height discriminator
- USB interface for computer logging

POWER/AUDIO AMPLIFIER

- True bipolar amplifier
- DC – 20 kHz, 10 V p-p, 1 A output
- Low impedance output

HALL EFFECT PROBE

- Measure the magnetic fields you teach
- High sensitivity 2 x 10^{-6} T
- Student calibration of probe

ULTRASONIC EXPERIMENTS

(Collaboration with GAMPT/Germany)

SET 4 ADVANCED APPLICATION OF PULSED ULTRASONICS

TeachSpin is the designated distributor in the US of the complete line of GAMPT Ultrasonic instruments. We carry all the GAMPT apparatus including Doppler measurements, medical applications, acousto-optic effects, and computer tomography. Any of GAMPT's standard 'sets' or custom made 'sets' can be obtained through TeachSpin. Our proprietary manual is only available through TeachSpin.

DEBYE-SEARS EFFECT, *The Basis of Acousto-Optic Modulation*

- Investigate velocity of propagation, frequency dependence, wavelength, acoustic impedance and absorption coefficients in both liquids and solids
- Observe and characterize both compression and shear waves in solids
- Learn non-destructive detection of imperfections, cracks, vacancies, and defects in solids
- Study the effects of both impedance matching and mismatching at material interfaces
- Create an ultrasonic diffraction 'grating' using the CW generator and the broadband ultrasonic transducer (Debye-Sears effect)
- The proprietary TeachSpin instruction manual emphasizes the basic physics of ultrasound measurements, gives references to the literature, provides self-discovery student experiments, encourages data collection on digital oscilloscopes, and offers self-directed student projects
- Learn experimental skills transferable to other pulsed time-domain investigations

Training at TeachSpin

A full day of personal attention from the physicists who design and build our apparatus will prepare you to teach a new instrument with confidence or offer an opportunity to explore more advanced applications of an old favorite.

Come alone or with a colleague. In addition to enhancing your instructional and technical expertise, you will get a chance to see the TeachSpin factory in action. You might even find yourself chiming in, over lunch, as we brainstorm development ideas for our next great experiment.

About TeachSpin

Started in a basement to build a table-top Pulsed NMR designed specifically for teaching, TeachSpin now offers a wide range of instruments to an increasingly international constituency. We keep on growing into our mission – to build rugged, reliable, and affordable, hands-on instruments that make it possible for any institution, regardless of its size or the particular specialties of its faculty, to teach a wide variety of modern and classic advanced laboratory experiments. And, while teaching important concepts and experimental skills, TeachSpin instruments provide a 'wide intellectual phase space', with choices of parameters and open-ended investigations that give students real ownership.

Many TeachSpin instruments were developed in collaboration with faculty who have created unique experiments for their own students and worked with us to make them available to the entire physics community. Now, partnering in another venue, we have created teaching materials and hardware that use electronics developed by other companies. UltraSonics uses GAMPT signal generators and transducers to explore the physics of a field important in both research and medicine. Fourier Methods, designed around the Stanford Research Systems updated SR770, introduces students to the incredible power of Fourier thinking, providing insights that may well enhance their contribution to whatever field of experimental or theoretical physics they pursue.

All of us here at TeachSpin share a passionate commitment to advanced laboratory education and to the faculty and staff who are making sure that this generation of students will have the tools to make tomorrow's new discoveries.

Barbara and Jonathan

2495 Main Street, Suite 409 ⧫ Tri-Main Center
Buffalo, New York 14214-2153
Phone: (716) 885-4701 ⧫ Fax: (716) 836-1077
www.teachspin.com

Individual parts, such as proprietary photodetectors and the optical pumping light source, are available upon request.