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Handy Hall Here
www.teachspin.com

The Relaxation Times

2495 Main Street
Buffalo, NY 14214
716-885-4701
fax 716-836-1077

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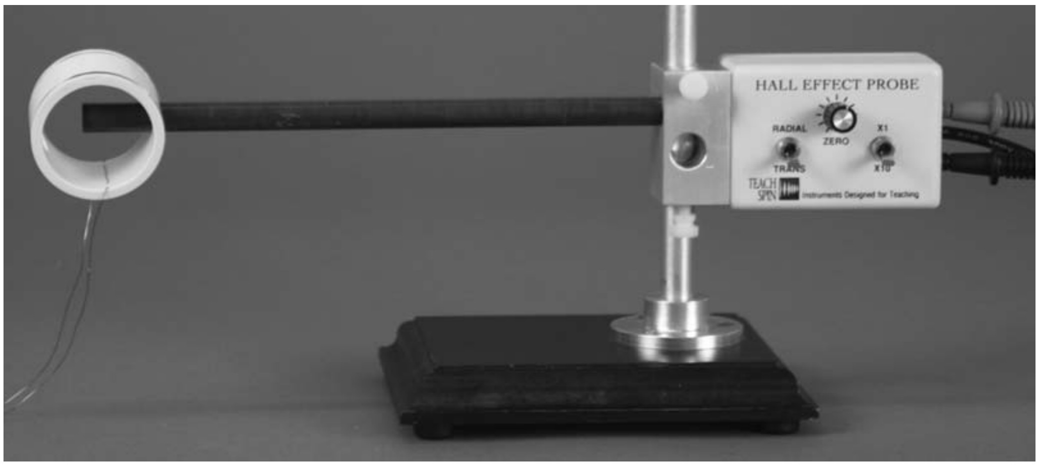
Using the Handy Hall Effect Probe



There are many commercial Hall effect sensors that will measure local magnetic fields. What gives us the "chutzpah" to recommend that you purchase our HE1-A unit? Does it measure magnetic field over a particularly large range? No! Is it extremely accurate? No! Does it have a digital output? No! Does it store data? No!

So why should any school want it? The answer is simply that ours is the only Hall-effect sensor ***designed specifically for teaching***. It was the teaching of students at all levels, from advanced placement kids in high school to junior physics majors in college that focused our design efforts when the unit was conceived. This device not only provides the student with valuable data, it "asks" the student to think about how this data is generated. Let me explain.

We believe students should understand that the Hall effect is the interaction of a current through a material with an external magnetic field that produces a voltage difference proportional to the magnetic field. With TeachSpin's new Hall Effect Calibration Kit (HECK1-A), students measure the dc output voltage and experimentally determine that it is linearly related to a magnetic field that they themselves create. It is the student who determines the proportionality constant. Thus, students calibrate the very instrument they will then use to measure unknown magnetic fields. The assembled kit is shown in the figure.

The plastic cylinder has two grooves cut to provide a channel for the wire with the proper geometry for creating a student-wound Helmholtz coil. So, instead of believing canned data on the number of turns and the dimensions of a large cross-section coil with many hundreds of turns, each student can wind his or her own coil with the magnet wire included, and then use this coil to calibrate their personal Hall-effect probe. How many of your students have ever wound a coil? How many will wind it incorrectly and produce a linear field gradient with zero field at the center?

HECK1-A

With this calibration kit, students have options. They can choose the size of the wire, the number of turns, and the directions of the windings. They have the chance of winding the system incorrectly and learning from their mistakes. They can also discover what is <u>not</u> relevant. Using only the Biot-Savart law, they can calculate the on-axis magnetic field at any point, including, of course, the center. Thus they can calibrate their instrument from first principles, relying only on the accuracy of their measurements of the dimensions of the coil form and the magnitude of the current.

Our HE1-A probe has a zero adjust that is extremely useful. It allows the student to cancel out the signal from the local "earth's" magnetic field. Since this Hall-effect meter was designed to measure fields significantly smaller than the Earth's field, it is very helpful to be able to cancel out the signal from this extraneous field. Therefore, if the probe itself is not moved during a measurement, and the local field signal is set to zero by this adjustment, the unit directly measures the magnetic field from the "magnet" being tested.

This unit was designed to measure magnetic fields created by the current configurations discussed in introductory texts on E & M. Almost every text works out the field as a function of distance from a long straight wire carrying a current I. This is often worked out theoretically using Ampere's Law and checked using the Biot-Savart integral. So our students should be familiar with this result. The field decreases as 1/r and it forms a circular pattern around the wire. Nobody at TeachSpin, however, has ever known a single student who actually measured this, or knows of any school at which this measurement is included in any part of the lab curriculum. You might want to consider adding this basic measurement to your lab. Here is a plot of our data using 10 amperes through a wire 1 meter long.

Again, students have some choice as to how they wish to make the measurement. The hard way is to leave the probe in the same place and move the wire. The better way is to move the probe and turn the current on and off and calculate the field from the difference in the two readings. The wrong way is to move the probe and to forget that the local Earth's field is, most probably, NOT the same over the region that the probe has been moved. Again, this is an experiment which gives the student real choices, and thus ownership of the experiment.

The Hall sensor can easily be used to check the field homogeneity and the field gradient linearity produced by the coils in both the Magnetic Force and Magnetic Torque apparatus. This can be done for both the on-axis field, where it can easily be calculated, and off-axis where the calculation is significantly more difficult. In any case, we believe that it is important for students, even theoreticians, to actually measure the field profile of a Helmholtz pair at least once in their physics.

I do not want to forget to mention the measurement of the on-axis field dependence as a function of distance for a small uniformly magnetized disc, which can be modeled as a small current loop. Measuring the field along the axis of magnetization as it varies with distance not only demonstrates the $1/r^3$ dependence (which will surprise many students) but also yield an accurate measurement of the dipole moment of the magnet. This is the *fifth* independent way of measuring the magnetic moment of the spheres used in the Magnetic Torque experiment. (That's right, fifth —- five independent measurements of Ì!) And this system could also be used to make a second independent measurement of the magnetic moment of the dipole used in Magnetic Force.

Lastly, I want to remind the reader of the unusual sensitivity of this two axis magnetic field probe. It is capable of measuring 2 ÌT, or, in the units I think with, 0.02 gauss. The Earth's field is about 0.5 gauss or 50 ÌT in North America. So this probe can measure fields about an order of magnitude smaller than the "background" local Earth's field. Of course, it can also be used to measure the Earth's field itself.

We think every lab should have at least one TeachSpin Hall-Effect Probe, and every teaching lab ought to have one for each team of students.

Greensboro AAPT Reception for ALPhA

The second RALI, Reception for Advanced Laboratory Instructors, overflowed the Augusta Room at this summer's AAPT meeting in Greensboro, NC. Among the guests were AAPT's Executive Director Toufic Hakim and past president Dick Peterson who has been an outspoken advocate for the advanced lab in both AJP and the new Interactions journal.

Jonathan Reichert and Dick Peterson

Current AAPT President, Harvey Leff, offered a "formal" greeting to the gathering and welcomed the interest in the quickly growing Advanced Laboratory Physics Association – ALPhA. The Advanced Lab website (www.advlabs.aapt.org) and listserve, which Leff initiated last November, have provided a much- needed forum for the exchange of ideas and expertise among advanced lab faculty and staff. He reported that a committee has been formed, headed by Ramon Torres-Isea of the University of Michigan, which will be working on organizing the AAPT's Advanced Lab website.

After an almost brief welcome and history of ALPhA from Barbara Wolff-Reichert, Jonathan took the floor to talk about the current state of the membership and some of his hopes for the organization. By late July ALPhA grew to 137 members (!), about one third of whom volunteered to take on leadership roles. With a little bit of luck, the Constitution and Bylaws will be voted on in September, and the process of electing officers and executive board will be completed by the end of October.

One of the "ALPhA ideas" dearest to Jonathan's heart is the creation of a team of "Mobile Mentors" who could travel to an inviting institution and become an on-site expert offering advice and hands-on support for the local lab instructor. Such a project would require not only finding the mentors but also acquiring a source of funding. Other projects would include helping to organize a Gordon Conference, proposing and participating in sessions devoted to upper division labs at conferences hosted by AAPT, APS, and OSA, advocating for time allocations within sessions that are appropriate for presenting and operating new apparatus, and arranging for pieces of, or an entire apparatus, to be brought to a conference by the presenter.

Becoming Part of a "Fine Structure"

Jonathan also addressed a couple of important concerns. One was the role of TeachSpin in relation to ALPhA. He reminded everyone that the idea for this organization was brought to us by Krishna Chowdary and that we were delighted to be able to offer significant financial and administrative support. Thus far we have funded two receptions at national meetings, used our staff to create a data base of members, and used this newsletter to inform the physics community about ALPhA. We will continue to match dollar for dollar all dues for the first year. Obviously, the existence of an organization like ALPhA and the increased attention to the upper division lab will benefit TeachSpin. We also hope to be able to collaborate with some of the ALPhA members to bring new instruments to the commercial market.

TEACH SPIN

Tri-Main Center, Suite 409
2495 Main Street
Buffalo, NY 14214-2153

Greensboro AAPT Reception for ALPhA *(cont.)*

Jonathan's other concern is that ALPhA not be caught up in what he called "turf wars" amongst the various physics organizations. While the ALPhA leadership may decide to undertake some projects on its own, much of what it does will be in conjunction with existing organizations, facilitating events and cross pollination, because its members will belong to a wide variety of groups both here and abroad. We expect that ALPhA will have affiliations with not only AAPT and APS but also OSA, MRS and, perhaps, like-minded groups in Europe, Asia, South America, and Australia.

If you would like more information about ALPhA, please check out the Adv. Lab Physics Assoc. tab on the TeachSpin website. There, we have posted links to the AAPT advanced lab website and listserv, as well as an invitation to become a member of ALPhA.

Standing Room Only at ALPhA Reception