Physics at Brown

News for Alumni and Friends **Issue 1 - Spring 1999**

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Hello! Greetings from the Brown Physics Department. Brown is ever renewing itself, and we in Physics also. We want to express with this new cycle of newsletters some of what we are now and where we are moving. To this end, we are focussing this first issue on new and special aspects of the Department: our newest faculty members, our renewed observatory, and a very special achievement by an undergraduate. Also, physics lecture demonstrations have risen in excellence to the point that even our new President aspires to be a demonstrator; and we couldn't leave out that story.

At Brown the physics faculty is heavily into research *and* teaching, and what makes Brown rather special is an emphasis on this combination of teaching and research as captured by the phrase "University/College". Our undergraduate concentrators work closely with faculty and graduate students in research projects; we list some recent Sc.B. theses along with Ph.D. theses. The abundance of forefront research activity by our graduate students is evident in this list, and we celebrate one particular award winning project.

We emphasize recent aspects of the Department, but the senior faculty and staff deserve mention and will be featured in newsletter issues to come. Also, to a very large extent the Department is all of us, all the students, faculty, staff, alumni and friends. The experience at Brown involves learning by both the faculty and their students, together. In Physics we want to maintain these mutual ties. We encourage visits and participation in colloquia, and really benefit from the interest and feedback from friends. Warren Galkin's (Sc.B. '51) involvement is especially noteworthy. As the Department evolves we cherish the memory of those who have devoted their lives to service at Brown. Professor Russell Peck passed away recently, and we invite all our friends to a Memorial Service (*see page 2*).

Finally, I must say that I'm delighted that our new Executive Officer Jim Valles has been so effective in putting together this newsletter, with superb help from Jane Martin. I hope that you enjoy reading it!

— *Dave Cutts, Chair,* cutts@brown.edu

Re-opening Ladd Observatory

Ladd Observatory is widely recognized as a small but beautiful gem in our nation's crown of historic public places of science. It was founded in 1891, when public excitement about the possibilities of the emerging field of astrophysics was intense, and people from Boston to Los Angeles would visit the observatory on the hill to see the latest comet, or observe a planet, or ask the astronomer a question about the universe.

Ladd Observatory

More than 100 years later, the accelerating pace of astronomical discoveries has created a surge of public interest in astronomy in Rhode Island as well as a strong interest on the part of students as demonstrated by growing enrollments in astronomy courses. Use of Ladd, which is coordinated by the Physics Department and Ladd Director, Dave Targan, has grown steadily because of this rise in interest. Three years ago, however, we had to temporarily close Ladd to bring it into compliance with modern building codes.

During this period, Brown invested almost $1-million in an extensive renovation of Ladd. The renovation improved several aspects of the observatory. An abandoned house on one corner of the lot was removed and the resulting open space landscaped into an inviting park which accentuates the simple architectural beauty of the old observatory, suddenly making obvious the connection between building, dome, and sky. The roof of the observatory was repaired and a railing installed, and the electrical system was upgraded. A tastefully designed elevator/stair tower was built with brownstone from the abandoned quarry used to build the original observatory; it now provides effective crowd management as well as access to disabled persons.

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The Galkin Foundation Fellowship

Warren Galkin '51

Warren Galkin '51 made possible the award this year the Galkin Foundation Fellowship, presented to a senior graduate student of exceptional promise and achievement in physics.

Mr. Galkin, a Rhode Island native, received an Sc.B. in Physics at Brown. He obtained an MBA in 1953 from the University of Pennsylvania Wharton Graduate Division. After a tour of active duty as a Naval Officer, he continued in the Naval Reserves, retiring as a Lieutenant Commander in 1977. Mr. Galkin owns the Natco Products Corporation with his brother Robert, Brown '49. Throughout his active business career, Mr. Galkin has maintained a lively interest in physics.

Mr. Galkin recognizes that Brown, with its superb undergraduate college, needs also to focus on its Graduate School. Indeed, Brown's special nature as a University/College rests on a strong synergy between graduate and undergraduate activities. Mr. Galkin enjoys his involvement with Physics faculty and students. The Department is most grateful for his interest and generosity.

Physics at Brown
Issue 1 - Spring 1999

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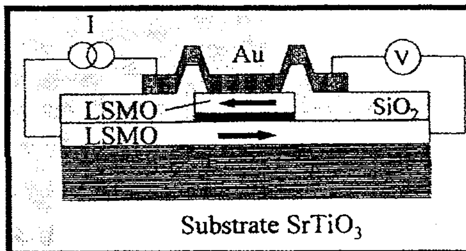
Your software demands more memory and your graphics files require more space on your hard drive. We all seem to quickly run out of memory space in our computer. Fortunately, it is relatively easy and inexpensive to upgrade a hard drive, and new computers typically come with a drive at least 5, if not 10's of GB in size. These large capacities are made possible by a new technology, which is having a big impact on the information storage industry. The giant magnetoresistance (GMR) effect, discovered only a dozen years ago by physicists, has allowed the areal storage density of hard drives to double every 15 to 18 months. Xin-wei Li, recipient of the Galkin Foundation Fellowship, investigates phenomena important to the next generation of hard drive magnetic sensors.

Xin-wei Li is a senior graduate student in Professor Gang Xiao's group who has always been interested in exploring new technologies that can drive the information revolution. Gang's ongoing research investigations of magnetoresistive materials provided him with a prime opportunity. With support from NSF, Gang has been studying electron transport and magnetism in low dimensional systems such as metallic thin films, superlattices, and ultrafine particles. Some of the specific topics involve giant and colossal magnetoresistance effects in layered and oxide solids, spin-dependent magnetic tunneling effects, and the physics of novel magnetic nanostructures. In 1997 and 1998, Gang attracted two IBM Partnership Awards for developing new magnetoresistive materials for information storage devices. Not only have these awards funded Li's investigations, but they have provided him the opportunity to perform fundamental research in IBM's TJ Watson Research Laboratory.

The GMR sensors used in the modern hard drives are resistors whose resistances change by a large amount when placed in a small magnetic field. A typical GMR structure consists of layers of magnetic and non-magnetic materials, each with a few nanometers (10^{-9} m) in thickness. The high magnetic sensitivity is caused by the strong interaction between the spins of conduction electrons and the magnetic moments in the multilayers. To push beyond the limits of this technology, Mr. Li has been studying new generations of GMR sensors based on magnetic tunneling junctions. He has succeeded in obtaining a large GMR effect in such systems. Recently, he is studying half-metallic magnetic systems, in which the spins of the conduction electrons are fully polarized. These new materials promise an even larger magnetoresistance effect than current GMR sensors.



Schematic diagram of a magnetic tunnel junction. The two magnetic electrodes

Xin-wei works very hard and has been very productive. His accomplishments are exceptional for such a young physicist. He already has co-authored ten scientific papers and been lead author on five of them. Some of these papers have received wide attention and have led to invitations to Professor Xiao's group to give review talks at the Materials Research Society meeting and other conferences. In addition to the Galkin Fellowship, he has received the Sigma Xi Research Award and IBM has provided him with a Summer Research Internship.

Professor Russell A. Peck, Jr.

Russ Peck, a close friend and mentor to both students and faculty during his 39 years at Brown from 1948-1987, passed away on March 7th. A Service in his memory will be held in Manning Chapel, Brown University, at 4 pm on Thursday, April 8, 1999.

The Demo Area Rules

An essential part of physics education is observing and getting the chance to experiment with the physical phenomena described in courses (remember 201 or the Van de Graaf generator?). About 10 years ago, former Department Chair, Bob Lanou, gave a substantial shot in the arm to Brown's effort to provide these opportunities by recruiting Mr. Dean Hudek as Laboratory Physicist and Director of Lecture Demonstrations. The demonstration area has become so successful that faculty demands for its services stretch it to new limits each year, their capabilities have received recognition on the national level, and their demonstration shows are locally famous.

When Mr. Hudek arrived from Arizona, he organized and upgraded the lecture demonstration area, adding new demonstrations and organizing the old ones. In the words of former Department Chair, Tony Houghton, he transformed it into a "World class show case." Commonly performed demonstrations now range from the simple yet thought provoking, "The Physicist Detector" which involves a plastic soda bottle, water and some secret ingredients (President Gee has one of these on his desk, a gift from Mr. Hudek, see back cover), to the highly technical, "Three Properties of Super Fluid Helium", which Mr. Hudek presented at last summer's American Association of Physics Teachers meeting, or "Looking at Atoms", which employs a Scanning Tunneling Microscope.

Faculty have come to rely heavily on demonstrations to supplement their lecures. Frequently, during the 10:00 class hour, three different classes require demonstration support and, under such

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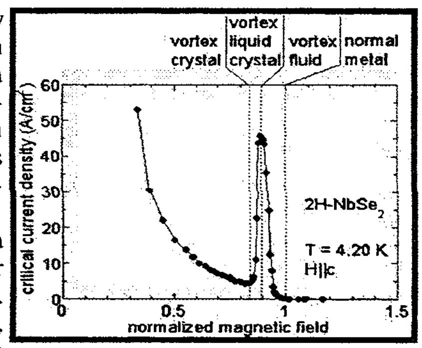
Apker Award Finalist Studies Vortex Matter

What is the defining property of a solid that distinguishes it from a liquid? How do solids melt? While kindergartners who have enjoyed ice pops may find such questions simple, they are, in fact, some of the most difficult unsolved fundamental questions in condensed matter physics. Sylvia Joan Smullin's (Brown '98) investigations of these issues earned her a place as one of three finalists for the American Physical Society's Apker Award for "outstanding research by an undergraduate student at a Ph.D. institution" and an invitation to present her results at the upcoming APS Centennial Meeting at Atlanta in March 1999. Ms. Smullin performed her senior thesis research on magnetic vortex solids under the watchful eye of one of our newest faculty members, Professor Sean Ling. Ling has created a research lab for investigating fundamental issues in condensed matter physics using various model systems.



Smullin worked on a type-II superconductor 2H-$NbSe_2$, held at 4.2 K. At this low temperature, the conduction electrons in the metal enter a superconducting state, forming Cooper pairs that can move through the atomic lattice without dissipation. In the presence of a moderate magnetic field, vortices of Cooper pair

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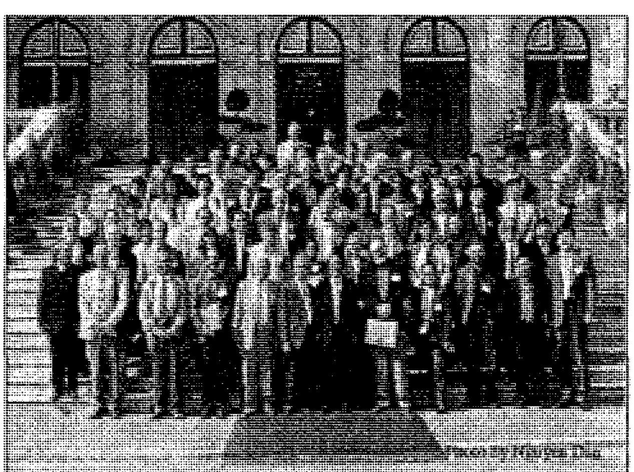
Three Faculty Members Participate in Vietnam Workshop



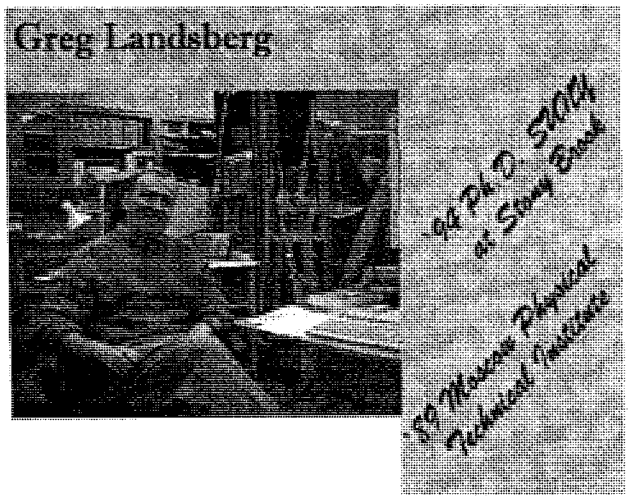
President Luong with conference participants at the Presidential Palace

Three of our Physics Department Faculty attended the Rencontres du Vietnam International Workshop on Superconductivity, Magnetoresistive Materials and Strongly Correlated Quantum Systems which was held in Hanoi, January 4 through January 10, 1999. Professor Gang Xiao was a member of the Scientific Program Committee and he, Professors Herbert Fried and Brad Marston were invited to give lectures in their research fields.

The conference reviewed recent progress in experimental efforts and theoretical developments. It focused on properties of the normal and superconducting states of high Tc superconductors, spin-polarized transport, colossal magnetoresistance, and strongly correlated quantum systems.

Many scientists from North America, Europe, and Asia attended the conference. They engaged in lively discussion of physics, and visited Vietnamese scientific institutions. The participants had the opportunity to meet the Vietnamese President and the United States Ambassador to Vietnam. They also met a group of Vietnamese physics students.

Our Newest Faculty



Greg Landsberg, who arrived in July of 1998, focuses his research activities on particle physics at the energy frontier—the DØ experiment at the Tevatron proton-antiproton collider at Fermi National Accelerator Laboratory. Profs. David Cutts, Richard Partridge, and Landsberg lead the efforts of Brown's High-Energy Physics (HEP) group at Fermi Lab in pursuit of unknown features of nature at the smallest distance scales ever probed by human kind.

The "Standard Model" (SM) explains physical phenomena at length scales down to 10^{-18} m (the shortest experimentally probed). Landsberg, Cutts, Partridge and their colleagues in the DØ detector collaboration helped to establish its validity by using the Tevatron collider. The Tevatron accelerates proton and antiproton beams to energies nearly one thousand times their rest mass: the highest energies ever achieved in a lab. By the Heisenberg uncertainty principle, the higher the beam energies the shorter the distances or the finer the structure probed. These beams collide in the center of the DØ detector, producing new, heavy particles that decay into lighter detectable species such as elec-

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The goal of high energy physics is to understand the fundamental laws of nature by considering phenomena at the smallest possible length scales. The Standard Model of the strong and electroweak forces has been enormously successful in accounting for the particles and interactions, within the reach of today's accelerator experiments. Many fundamental questions, however, are beyond the Standard Model. For example, what determines the specific masses and numbers of particles? and how can gravity, the one force not included in the Standard Model, be quantized so that it can be included in theories of phenomena (e.g. black holes) in which its influence equals that of some of the other quantized forces? Such questions fall within the interests of David Lowe, who joined the Brown faculty in 1997. Professor Lowe works in string theory, quantum gravity, quantum field theory and black hole physics.

Since present experiments cannot directly probe physics at the very small length (high energy) scales necessary to observe the influence of gravity on particle interactions, theoretical physicists are taking a top-down approach in efforts to go beyond the Standard Model. That is, Lowe and others are trying to construct a consistent theory at the highest possible energies

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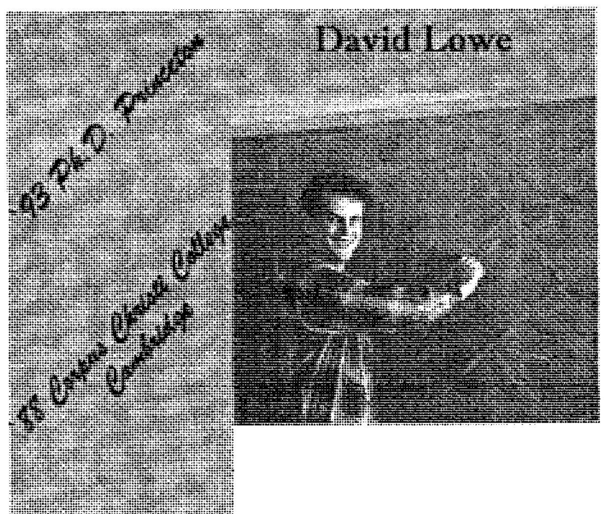

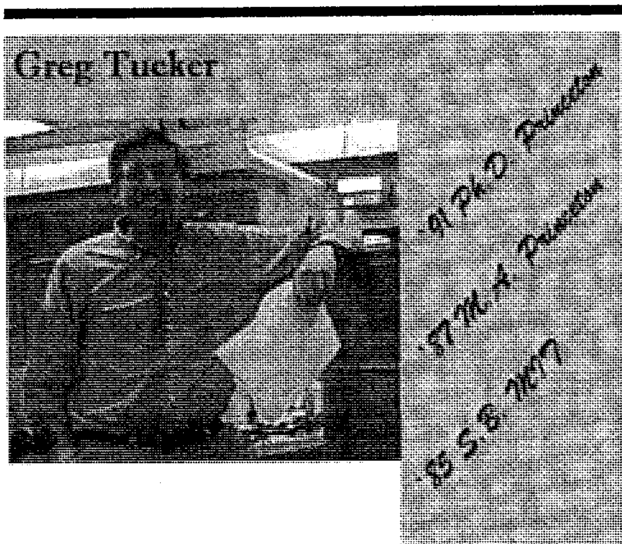

The oldest light in the universe contains important information about the origin, the fate, and the present make-up of the universe. This light, the so-called cosmic microwave background (CMB) originated in the Big Bang and permeates the entire universe. Greg Tucker, who joined the faculty in 1997, studies the CMB as a means to address such cosmological issues.

The small spatial temperature variations in the CMB contain the imprint of the small density fluctuations in the early universe that led to the large scale structure which we observe in the universe today. By measuring the angular power spectrum of the temperature variations (anisotropy) and polarization of the CMB, it should be possible to answer fundamental cosmological questions. For example, inflationary models predict a series of so-called Doppler peaks in the spatial power spectrum. Values of cosmological parameters can be determined by measuring the shape of the power spectrum, including the positions and heights of the peaks. By knowing these values we will learn such things as the age of the universe and whether it will continue to expand

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Recent PhD Recipients

1998

LUIS ABRAMO, "The Back Reaction of Gravitational Perturbations and Applications in Cosmology", *Advisor: Prof. R. Brandenberger*

BRIAN BLAIS, "The Role of the Environment in Synaptic Plasticity: Towards an Understanding of Learning and Memory", *Advisor: Prof. L. Cooper*

CHADWICK CANEDY, "Magnetotransport and Magnetic Properties of Manganites and Platinum-Based Alloys/Superlattices", *Advisor: Prof. G. Xiao*

WILLIAM CAPINSKI, "Thermal Conductivity of (GaAs)n/(AlAs)n Superlattices and Isotopically Enriched Si and GaAs", *Advisor: Prof. H. Maris*

JAMES CHERVENAK, "Studies of the 2D Superconductor-Insulator Transition in Quench Condensed Films", *Advisor: Prof. J. Valles*

GUOQIANG GONG, "Colossal Magnetoresistance Effect in Natural and Artificial Manganite Structures", *Advisor: Prof. G. Xiao*

STEPHEN HAHN, "Functional Methods of Weighted Residuals and Quantum Field Theory", *Advisor: Prof. G. Guralnik*

PARAG V. KELKAR, "Stimulated Emission, Gain and Coherent Oscillations in II-VI Microcavities", *Advisor: Prof. A. Nurmikko*

ROSS LARSEN, "Static and Dynamic Properties of Molecules Dissolved in Liquids", *Advisor: Prof. R. Stratt*

JACKSON LOOMIS, "Investigations of Evanescent Heat Transfer and Measurements of the Acoustic Reflection Coefficient for Thin Metal Films", *Advisor: Prof. H. Maris*

YU LU, "An Experimental Study of FM-I-FM Tunnel Junctions", *Advisor: Prof. G. Xiao*

ALEXEY ONUFRIEV, "Synergetic Approach to Many-Body Problems: From Scattering Charge Transfer to Arrays of Quantum Dots", *Advisor: Prof. J.B. Marston*

KONSTANTINOS ORGINOS, "QCD Vacuum, Improved Actions for Heavy Fermions and Chirality", *Advisor: Prof. C-I. Tan*

AMY PERKINS, "Experimental Studies of Light Propagation in Active Scattering Media", *Advisor: Prof. N. Lawandy*

MIHAIL SIMKIN, "Numerical Studies of Josephson Arrays and Spin and Gauge Glasses", *Advisor: Prof. M. Kosterlitz*

PREDRAG STOJKOV, "Heat Kernels, Lasers and Ordered Exponentials", *Advisor: Prof. H. Fried*

JOHN THOMPSON, "Pump-Probe Low Energy Electron Diffraction", *Advisor: Prof. P. Estrup*

SAMEER VARTAK, "Applications of Anolmalous Diffraction Systems, Generation of Attosecond Electron and Photon Pulses, and Raman Amplifcation by Stimulated Emission of Radiation", *Advisor: Prof. N. Lawandy*

ILYA VEKHTER, "Quasiclassical Approach to Transport in the Vortex State of Type II Superconductors and the Hall Effect", *Advisor: Prof. A. Houghton*

GRANT WILSON, "An Instrument and Technique for Measuring the Anisotropy in the Cosmic Microwave Background Radiation", *Advisor: Prof. P. Timbie*

1997

RAM M. BALACHANDRAN, "Laser Action in Scattering Gain", *Advisor: Prof. N. Lawandy*

HUXIONG CHEN, "Laser Induced Effects in Carbon Suspensions and Diffraction by Volume Gratings in Liquids", *Advisor: Prof. J. Diebold*

STEWART CRALL, "Aspects of the three-Body Problem in Two spatial Dimensions", *Advisor: Prof. F. Levin*

ANTONELLA CUCCHETTI, "Microscopic Models for Adatom Dynamics", *Advisor: Prof. S-C. Ying*

DAVID CULLEN-VIDAL, "Color Coherent Radiation in Multi-Jet Events fm Proton-Antiproton Collisions at the DZERO Detector", *Advisor: Prof. D. Cutts*

THOMAS FAHLAND, "Test of the Electroweak Sector of the Standard Model by Measuring the Anomalous WWCouplings", *Advisor: Prof. D. Cutts*

VLADIMIR KOZLOV, "Biexcitonic optical gain in a ZnSe single QW", *Advisor: Prof. A. Nurmikko*

JAE H. KYIUNG, "Microscopic processes for second harmonic generation and applications of selective etching effect in photo-encoded glasses", *Advisor: Prof. N. Lawandy*

MOISES ORENGO-AVILES, "NMR and NQR Studies of Quadrupolar Effects in Glasses and Polycrystals with Half-Integer Spins", *Advisor: Prof. P. Bray*

ALEXANDER SMONDYREV, "Computer Simulations of Liquid Crystals", *Advisor: Prof. R. Pelcovits*

HAEYEON YANG, "Molecular Beam Scattering Studies on Si(111)-7x7, Si(111)-H (1x1), and Si(111)-D(1x1) Surfaces", *Advisor: Prof. E. Greene*

Recent Senior Honors Theses

1998

SYLVIA SMULLIN, "The Peak effect in Superconductors", *Advisor: Sean Ling*

MARGARET GARDEL, "The Magnetic and Metal-Insulator Phase transitions in $La_{(1-x)}Ca_xMnO_3$ Near x=0.50", *Advisor: Gang Xiao*

WEI MUN WANG, "Perturbative Calculations in Quantum Field Theory Using Sinc Functions", *Advisor: Gerry Guralnik*

JOSHUA BLOUSTINE, "Shapefinders: A New Diagnostic Tool for Large-Scale Structure", *Advisor: Robert Brandenberger*

ANDREW HASS, "Searching for the τ_l at DØ", *Advisor: Dave Cutts*

1997

ERIC A. GALBURT, "Static Magnetic Field Effects on the Development of Xenopus laevis", *Advisor: J. Valles, Jr.*

AMY LO, "Using Weak Gravitational Lensing to Distinguish Topologies of Structure Formation Models" *Advisor: R. Brandenberger*

JOHN MCGREEVY, "A String Model for Deconfinement Temperature at Nonzero Baryon Density", *Advisor: C-I. Tan*

CARA RAKOWSKI, "Time Series Analysis of GISP2 ion and O^{18} Data", *Advisor: J. B. Martson*

BHAVANMIT S. SURI, "Magneto-transport Properties of the Bulk MR Material $La_{(1-x)}Ca_xMnO_3$, *Advisor: G. Xiao*

The Demo Area Rules

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circumstances, the total number of different demonstrations can exceed 10. Moreover, some 100 level courses now routinely include demonstrations. The demand has grown in large part due to the presence of Mr. Jerry Zani, the Demonstration Technician, who arrived in the fall of 1993. Thanks to Mr. Zani's expert work, the daily coordination of demonstration setup, delivery, breakdown, and maintenance is transparent to the faculty. If Mr. Zani feels overworked, he has to partially blame himself. He enthusiastically offers suggestions to faculty seeking just the right demonstration and is constantly working to create new ones and improve old ones.

Outside the department, Mr. Hudek is best known around campus and in the local community for his physics demonstrations shows (for which Mr. Zani provides invaluable assistance). He presents his two hour "The Magic and Mystery of Physics" shows via the Brown Learning Community, or through private arrangements with local schools. The shows he and Mr. Zani presented for the last two Staff Development Days were very well attended and heavily praised. But, perhaps the pinnacle of all of this was when Mr. Hudek was allowed to give a one-hour private demonstration show to Brown's new president, E. Gordon Gee. President Gee enjoyed the show immensely, though he jumped considerably when a 55-gallon drum imploded.

In addition to his work in the demonstration area and in the upper level labs (where he has also made significant improvements), Mr. Hudek performs important professional service. On the national level, he was recently appointed to the American Association of Physics Teacher's (AAPT) Professional Concerns Committee. This appointment comes after several years of active involvement in the Physics Instructional Resource Association, a subdivision of the AAPT. Mr. Hudek's primary focus has been on helping Instructional Resource Specialists (Demonstration Technicians, Educational Lab Technicians, etc.) become more professional. He held well-attended Cracker-barrel sessions on the "Professional Concerns of Instructional Resource Specialists" at two consecutive AAPT summer meetings. The Professional Concerns Committee recently agreed to sponsor these cracker-barrel sessions annually. At Brown, Mr. Hudek is a member of the newly formed Staff Advisory Committee (SAC), formed by President Gee. It consists of about 20 staff members and its mission is to advise the President regarding issues of importance to the staff.

Apker Award Finalist

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currents form inside the metal. Remarkably, the magnetic flux carried by a single vortex is quantized because of the quantum mechanical origin of the superconducting state. The vortices repel each other and form an ordered array that can support shear: a vortex crystal inside the atomic crystal! It turns out that the vortex crystal is as soft as jello. In 1988, three condensed matter theorists at Brown, Professors Tony Houghton and Bob Pelcovits and former graduate student, Asle Sudbø, (Ph.D. '90) and Harvard theorist Professor David Nelson, predicted that, as in regular solid matter, the vortex crystal should melt when heated. When the lattice melts, the loss of its shear rigidity leads to an anomalous peak in the critical current density due to random impurities in the atomic lattice (see figure, p. 3). By studying the temperature and field dependences of this peak effect, Smullin showed that the vortex lattice melting may involve an intermediate vortex phase similar to that found in liquid crystals.

Arthur O. Williams Lecture:

"Craft and Art in Experimental Science"
Professor Martin Perl

April 26, 1999, 4:00 pm B&H

Greg Landsberg

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trons, muons, tau-leptons, or photons. Data acquired by the DØ collaboration during the 1992-96 Tevatron run provided a number of precision tests of the Standard Model of electroweak interactions: the interactions responsible for the stability of atoms, the radiation of the sun and other stars, and chemical reactions. Among the tests were the discovery of the top quark (the sixth, and possibly the last quark) and the precise determination of its mass and pair production cross section. In addition they measured the W-boson mass to 0.1% precision, studied trilinear couplings between gauge bosons (W, Z, and photon), and searched for the Higgs particle.

While the Standard Model has passed these many stringent tests, High Energy physics still finds itself in a peculiar unsettled state. Even though the SM seems to work very well, it is known to be mathematically incomplete! Physicists believe that the SM is just an approximation of a more general theory because there are outstanding puzzles that it can not address. For example, the SM can not explain why the Universe contains more matter than anti-matter.

In some sense, this situation resembles that of Newtonian mechanics two hundred years ago. At that time, Newton's laws described the world accessible by the then available experimental means. In the beginning of this century, however, we learned that Newtonian mechanics breaks down for particles travelling at velocities approaching the speed of light and that it is just an approximation of a more general relativistic mechanics! "Nowadays," says Prof. Landsberg, "we are very lucky to know that the Standard Model has limitations, before deviations from its predictions are found."

There are very good reasons to believe that completely new physics will manifest itself at the distances just below those currently probed. Consequently, both the Fermilab Tevatron and the DØ experiment are undergoing a major upgrade. More experiments with yet higher (by 10%) beam energy and 20 times more expected proton-antiproton collisions are scheduled to begin next year.

The Brown HEP group is actively preparing, building hardware and trigger systems and developing highly optimized particle identification algorithms. In addition, Professor Landsberg leads the DØ Exotic physics group, which, among other things, uses existing data to place strong limits on the existence of new exotic objects, such as supersymmetric particles, leptoquarks and Dirac monopoles. He also convenes two Fermilab workshops on future searches for new physics. In short, he and his colleagues are preparing for a full-scale attack on the new physics, which, as many people believe, should be hiding just around the corner!

David Lowe

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which gives results compatible with what is known at low energies. "At first sight," Lowe remarks. "it might seem that we would be completely in the dark as how to come up with such a theory." Remarkably, over the past 30 years, a single approach known as string theory has appeared that may fit the bill.

String theory is most simply formulated in ten spacetime dimensions (six of which curl up, leaving us with our usual world with three space and one time dimensions). Consistency led to five different types of string theory, each of which contains certain coupling parameters. For small coupling parameters, string theory gives a well-defined set of rules for computing quantities, such as the masses of particles and their interaction strengths. This theory has undergone a revolution over the last four years. It is now realized that all the string theories are actually different aspects of a single theory which we call M-theory, which lives in eleven dimensions.

One of the original motivations for studying string theory and M-theory was to better understand quantum gravity. To make progress, a definition of M-theory is needed, beyond its description in different corners of parameter space as the known string theories. Recently such a definition of M-theory was proposed, but the exploration of this new formulation is still in its infancy. There are nevertheless many questions one can begin to address. For instance, a number of vexing paradoxes arise when we try to apply the usual rules of quantum field theory to black holes. Black holes are thought to arise when very large stars burn out, leaving a lot of matter behind which collapses under its own weight. The space around this object gets so highly distorted that anything that gets sufficiently close to it is captured. In the 1970's Bekenstein and Hawking used thermodynamic arguments to conclude that black holes should have a definite number of quantum states (or entropy) associated with them. Since a complete theory of quantum gravity did not exist at that time, they were never able to say precisely what the states were. In recent work Professor Lowe applied the new formulation of M-theory to this problem, and was able to describe the quantum states corresponding to black holes, confirming the state counting interpretation of the Bekenstein-Hawking result. While a final formulation of the "Theory of Everything," is still a long way off, results like this show that progress is being made in leaps and bounds.

Greg Tucker

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for ever or will stop expanding and collapse in a "Big Crunch".

Although the CMB was discovered in 1965 by Arno Penzias and Robert Wilson, it was not until 1992 that the Cosmic Background Explorer (COBE) satellite first observed anisotropy. (Polarization in the CMB has not yet been discovered although it is expected to exist. Since the expected level of polarization is no more than 10% of the temperature anisotropy, new experimental techniques will be required to detect it.) While experiments are not yet precise enough to determine cosmological parameters, the results do hint that an inflationary model for the universe is correct.

Two upcoming projects, MAP (microwave anisotropy probe) and BAM (balloon-borne anisotropy measurements) promise much higher precision anisotropy measurements. The NASA MAP satellite will measure the power spectrum of the anisotropy using radiometers that Tucker helped develop. BAM, the focus of a collaboration between Tucker and Physicists at the University of British Columbia, complements the MAP project as it measures a different part of the power spectrum. It has already flown once and will fly again this fall. These experiments should yield precise values of key cosmological parameters.

In an earlier CMB experiment, the White Dish instrument at the South Pole which set a strong upper limit on small scale anisotropy, Prof. Tucker developed the world's most sensitive single-mode bolometer. Based on this experience, he is continuing his efforts in detector development. He is currently pursuing a novel technique for fabricating an array of infrared bolometers, which will solve some long-standing issues in the fabrication and performance of such detectors.

For more information see http://cmbr.physics.brown.edu

Ladd Observatory

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All of this work was done in close consultation with the Providence Preservation Society and residents of the surrounding neighborhood. The entire project was done with an eye toward preservation, not modernization. The original manually wound clock drive was professionally cleaned and new naval rope was attached to the giant wheel on the hand-turned 30 foot copper dome. The effect is stunning-Ladd is still a place where you can directly experience the night sky and astronomy of the last century, even as we enter another one.

Upon completion of the project we discovered, almost to our own surprise, that Ladd was reborn as a highly visible and elegant structure, now more than ever connecting students and members of the community with the sky and the ancient science of astronomy. This increased visibility of the Department's reborn observatory has greatly accelerated what was already an enormous public interest in astronomy. Attendance at open nights has been double what it was prior to the renovation, now reaching an estimated 4,000 people per year. Requests by special groups for private sessions has increased from one per week to at least five per week. Finally, questions by members of the public and the media directed toward our staff range from five to fifteen per day.

We have been able to resume use of the observatory for evening laboratories for Physics 21, 22, and 24, which combined have an enrollment of well over 200 students. Although the new, very modern observatory on the roof of Barus and Holley is more practical for most purposes, and our remote site at Jerimoth Hill offers the darkest skies, Ladd still offers the best views of finely detailed targets such as the surface of Mars or the smallest craters on the moon. Moreover, students learn about the historic role of Ladd in providing time-keeping service for Rhode Island by seeing how clocks were calibrated by observations of star transits using the observatory's transit telescope. It also allows classes of students to connect to an ancient tradition of showing Brown astronomy students the splendors of the night sky using a great refractor housed in a beautiful old observatory.

Physics at Brown

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Brown University President Gee being tested to see if he is a potential Physicist. Of course, as with any Brown exam, the results will be kept strictly confidential.