Princeton Physics News

VOLUME 2, ISSUE 2 FALL 2006

INNOVATIONS IN TEACHING

Chair Daniel Marlow, teaching a session of the Integrated Science course in the "whale" classroom of Icahn Laboratory.

The Department of Physics has always been deeply committed to excellence in teaching, and very interested in reaching out to as many students as possible. In the past few years, the department has been involved in a number of innovative teaching endeavors, aimed at both majors and non-majors.

NEW PHYSICS COURSES FOR SCIENTISTS

INTEGRATED SCIENCE

Traditionally, students interested in the natural sciences and engineering take separate freshman-level courses in biology, chemistry, and physics. As science becomes increasingly interdisciplinary, this approach may no longer be the best, especially for those interested in biology, which is becoming increasingly quantitative. Leaders in the field of biology who served on a 11-member committee appointed by the National Academy of Sciences (including Princeton biophysicist John Hopfield) recently contrasted the profound transformation that has occurred in biology—driven by biotechnology, genomics, and computing—and the lack of change in the way the subject is traditionally taught. Princeton has taken the lead in addressing this problem by developing a new interdisciplinary approach to undergraduate science, in which instructors from different disciplines come together to create a single course: "An Integrated, Quantitative Introduction to the Natural Sciences." Rather than following the conventional curricula of those disciplines, the new course is organized around fundamental concepts and computational techniques common to all of them. At the same time, it fulfills the prerequisites of advanced courses that build on the conventional introductory classes. This course of study aims to display the practical connections among the fields of physics, chemistry, and computer science, and to incorporate the mathematical concepts scientists use. Two members of the

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CHAIR'S GREETINGS

Daniel Marlow

I was recently asked to make welcoming remarks at the symposium in honor of Professor Joe Taylor. It occurred to me that our visitors, many of whom were Joe's former students and collaborators and had been away from Princeton for a number of years, might like an update on the construction taking place on literally all sides of Jadwin Hall. Jadwin and its environs hadn't changed much since it was completed in 1968, with the notable exception of the Lewis Thomas Laboratory (for MolBio) across Washington Road, which was completed in 1986.

About 10 years ago, things began to change. The former Palmer Physical Laboratory, which was the department's home for nearly 70 years, was turned into the Frist Campus Center. James S. McDonnell ('21) Hall, designed by Gwathmey Siegel and Associates, was built between Jadwin and Fine to house modern lecture halls, teaching laboratories and classrooms, bringing the department's teaching and research activities into close proximity. Next was the Carl Icahn Laboratory, built in 2002 directly across Washington Road from Jadwin. The Icahn Lab, designed by Rafael Viñoly, houses the Lewis-Sigler Center for Integrative Genomics, in which there is strong physics department participation, in both research and instruction. It is a truly spectacular building, with an atrium café that has become a favorite place to eat lunch for many in the department.

As this is written, construction is well along on the new Peter Lewis Science Library. This building, which will consolidate the collections of several science department libraries, was designed by the

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physics department, biophysicist Bill Bialek and Chair Dan Marlow, have played a crucial role in this enterprise, which is a close collaboration among the departments involved. Marlow believes that the new course offers an alternative to the traditional way of teaching physics, and hopes that it will attract more students into physics. According to Bialek, the challenge is to add breadth to introductory science without sacrificing depth, which requires critical viewpoints from each field represented. His efforts in the course earned a President's Award for Distinguished Teaching, which is one of the highest honors given for teaching at Princeton.

EMP

The departments of physics and mathematics have teamed up with the engineering school to create an innovative series of courses that integrate their subjects into a multidisciplinary curriculum for freshman engineers, the EMP (Engineering-Math-Physics) freshman course. The physics department has been an active participant in this project, with physics professors Peter Meyers and Frank Calaprice teaching in the fall and spring terms respectively. Professor Marlow has worked on a new mechanics lab, the so-called "Rocket Lab." The EMP labs tend to be project-oriented, in contrast to the traditional freshmen physics labs, which are devoted to demonstrate fundamental laws of physics and replicate historically important experiments.

In the picture above, physics graduate student Vassilios Papathanakos (right) helps a freshman student build an electronic device that will measure the acceleration of a water-propelled rocket. Students devote all of the labs in one semester to building rockets and the associated instrumentation, launching the rockets, analyzing the acceleration data from the rockets, and comparing it to theoretical calculations.

NEW PHYSICS COURSES FOR NONSCIENTISTS

MUSIC AND PHYSICS

An example of innovative courses for nonscientists is Physics 116 "Music and Physics," taught by Professor Emeritus Pierre Piroué, which is designed for nonscientists who love music and would like to learn more about how it is made. This course is an outgrowth of a freshman seminar which Professor Piroué taught for three years. This seminar was oversubscribed every year, thus showing that freshmen who normally wouldn't consider taking a physics course can learn basic physics through music, and find the whole experience interesting and rewarding.

Unlike traditional courses in the physics of music that start with physical concepts and then move to the musical applications of those concepts, this course develops the physical concepts and musical applications simultaneously. This approach makes the course more accessible to nonscientists and better explains the interplay of music and physics. The course is organized as weekly laboratories preceded by introductory lectures. Physics and music demonstrations are an integral part of the course. Students playing an instrument are invited to bring their own instrument for demonstrations and individual projects.

FUTURE PHYSICS

Physics 115 "Future Physics," taught by Professor Steinhardt, aims to give nonscientists tools for decision-making by offering an introduction to concepts and techniques of physics that are likely to be important for future leaders in business and government. "Part of the course is purely about curiosity, but a lot of it has to do with physics that everyone needs to be concerned with in the future," Steinhardt said. "The goal is to try a new approach to communicate the importance of basic physics to key decisions that affect our lives." Topics include the physics of energy and power production and consumption; the nuclear physics of reactors and weapons of mass destruction; quantum physics and its potential role in the design of powerful new computers; and the physics of waves, from light waves to tsunamis. "The idea is to give students the basic information and the confidence that they can understand the important principles," Steinhardt said. "As nonscientists, it's not their job to calculate things, but they are going to have to judge whether ideas suggested by engineers and scientists are reasonable." Hence, among the assignments in the course, students will be asked to consider hypothetical public policy decisions that involve concepts of physics, choose a solution, and justify the answer. Students are not graded on the policy decision but on their use of sound physics and logical reasoning.

FROM THE CHAIR-continued from page 1

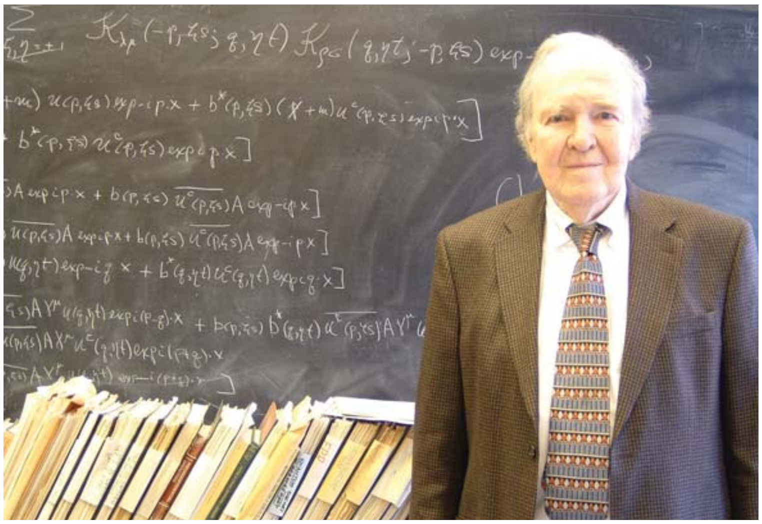
renowned architect Frank Gehry. Plans are also well advanced for two more structures to the south of Jadwin. One will be a pedestrian bridge across Washington Road that will provide a safe crossing and will serve as a symbolic gateway to the campus for traffic proceeding up Washington Road. The other will be a new 250,000 ft^2 chemistry building, to be completed in 2010, which will go where the Armory (and our parking lot!) now sits. Not too much later, two more buildings will be erected to the south of the Icahn Lab. One will house a new neuroscience institute (to be co-directed by physics faculty member, David Tank) and another will house the psychology department. José Rafael Moneo Arquitecto, a Madrid-based firm, has been chosen to design these buildings.

In addition, Jadwin Hall is itself in the midst of internal changes. The former cyclotron high bay has been turned into the Princeton Nanoscale Microscopy Laboratory, a 5000 ft^2 facility designed for high-precision measurements in condensed matter physics. Soon the fourth floor will be remodeled to be the home of the recently founded Princeton Center for Theoretical Physics.

As a result of these changes, Jadwin, which once sat at the geographic edge of the Princeton campus, will soon be in the center of a thriving "science neighborhood." In light of the department's leading role in many of the interdisciplinary developments of the past several years, this is highly fitting (and quite possibly even worth the loss of nearby parking!).

EMERITI

In the first issue of the physics newsletter published in winter 1989, David Wilkinson, then department chair, wrote: "Emeritus faculty members are active in Jadwin. We are fortunate to have such a distinguished group doing research, attending seminars, and interacting with students." This is still true today.



One of the current emeriti is mathematical physicist **Arthur Wightman**, renowned for his many contributions to field theory. He laid the foundations of axiomatic quantum field theory, which provided an elegant set-up in which physical results such as the PCT symmetry and the connection between spin and statistics became theorems.

Arthur is a walking encyclopedia and local history buff. It has proved impossible to interview him for this article. Not that he is not willing. When you ask him a question, he replies "Do you have a minute?" He then sits down and starts answering. But there is no quick answer for Arthur. He knows so much, he has so much to say, he has so many details to reveal and so many connections to make. You sit there listening to all these facts that he remembers in exquisite detail, totally fascinated. You forget where you started and have no idea where he is going. It takes you by surprise when finally he closes the multiple loops and sub-loops in his discourse, and gets back to exactly where he started. Hours later, you finally have the answer to the question you asked long ago, and in the process you have learned an awful lot about many things you did not even know existed, and you've enjoyed every moment of it.

Nuclear physicist **Rubby Sherr** received his undergraduate degree from New York University in 1934 and his doctoral degree from Princeton University in 1938. He joined the MIT Radiation Lab in 1942 and worked on the Manhattan Project at Los Alamos for two years in the Initiator Group, which designed the trigger used with the plutonium device at Trinity. After Los Alamos, Rubby joined the faculty of the Department of Physics at Princeton University, where he taught and pursued research in nuclear physics for 30 years and is now professor emeritus. Recently, he has worked in collaboration with Professor H. T. Fortune of the University of Pennsylvania.

Rubby never misses a Joe Henry lunch in the physics department. This is a monthly lunch meeting during which the faculty and research staff gather to discuss various departmental issues in graduate and undergraduate education, and to listen to a short research presentation. In the picture (bottom left) Rubby is shown with Val Fitch and Arthur Wightman, catching up on things while waiting for the meeting to start.

The formal part of the Joe Henry meeting always starts with the introductions of out-of-town guests. Since the time that Rubby moved out-of-town, it has become a tradition for Chair Dan Marlow to introduce at the Joe Henry lunches "our distinguished out-of-town guest Professor Rubby Sherr," an introduction always greeted with a round of applause.

Particle physicist **Frank Shoemaker** comes regularly to the department accompanied by his dog Teddy, a small white Cairn terrier (definitely the best-behaved dog in the world).

Frank arrived in Princeton in 1951 to lead several major accelerator projects before turning his interests back to particle physics in the early 1970s. Figuratively baptized in flame, Frank rebuilt the Palmer Cyclotron after a disastrous fire in 1952; and, in the course of his research, he and colleagues pioneered the strong focusing of particle beams via quadrupole doublets. Frank went on to lead the design and construction of the Princeton Pennsylvania Accelerator, and to head the design group at Fermilab for the Main Ring of the original accelerator.

Returning to Princeton in 1969, Frank took over from George Reynolds as principal investigator of the high energy physics contract, and for the next 35 years played critical roles in several Princeton experiments at Fermilab and Brookhaven Laboratory. In the 1970s, Frank worked on the Multimuon Spectrometer, designing and building its drift chamber system. The MMS was used for early studies of the then-new charmonium states and helped confirm the first predictions of the new quantum chromodynamics theory of the strong interactions.

In the mid-1980s, Frank's efforts were directed toward Brookhaven Experiment 787, a search for "flavor-changing neutral currents," predicted to occur at the 1-part-in-10-billion level in kaon decays. Frank's succession of Cerenkov counters helped the experiment explain this process. In his retirement, Frank continues to play a major role in the design of the Booster Neutrino Experiment, MiniBooNE, currently running at Fermilab.

PEOPLE AND NEWS

Lyman Page, the Henry De Wolf Smyth Professor of Physics at Princeton, has been elected to the National Academy of Science. He is the principal investigator with the Wilkinson Microwave Anisotropy Probe (WMAP) satellite, which in recent years has obtained a detailed map of the "cosmic microwave background," the remnants of the oldest light in the universe as it emerged from the fireball of the big bang. The satellite, which continues to pour in data, grew out of collaboration between NASA and Princeton, with additional contributors at other institutions. Currently, Lyman is also working on the ACT project, based in Chile.

Physicist **Nai-Phuan Ong** has been named a fellow of the American Academy of Arts and Sciences. The Eugene Higgins Professor of Physics, he joined the Princeton faculty in 1985. He is an experimental solid state physicist who works on high temperature superconductivity and various aspects of soft condensed matter physics.

Recent Ph.D. graduate **Yayu Wang** won the McMillan Award for work done with Professor Ong. The citation explains that the award was given "for his ground-breaking Nernst effect and magnetization torque experiments, which have established the existence of large vortex fluctuations throughout much of the pseudogap regime of the high-temperature superconductor LaSrCuO well above its critical temperature."

TEACHING PRIZES

The physics department is very aware of the important role that graduate students play as teaching assistants in the department. In recognition of their important contribution, at the end of every academic year the physics department presents teaching prizes to a few graduate students who have particularly distinguished themselves. In the picture, **Georgios Michalogeorgagis** poses after receiving his prize.

THE PRINCETON-GRANSASSO PROGRAM

During the last three summers the physics department has offered a summer program for high school students from Italy's Abbruzzo and Molise regions. This program stemmed from the scientific collaboration between the physics department at Princeton and the Laboratorio Nazionale del GranSasso, where Princeton scientists conduct research on neutrinos and dark matter in a tunnel under the GranSasso Mountain located in the Abbruzzo region.

RETIREMENT PARTY

Laszlo (Les) Varga, head of the Jadwin machine shop, retired from the University in February 2006 after 38 years of service. Les is seen here with Professor Bob Austin, congratulating him at a reception in his honor, where more than a hundred of his close friends from the department and the University were in attendance.

SYMPOSIUM

At a symposium and a retirement dinner on September 30, physicists and friends gathered to honor **Joe Taylor**, the James S. McDonnell Distinguished University Professor of Physics. Joe used binary pulsars to make high-precision tests of general relativity and to demonstrate the existence of gravitational radiation. The recipient of many awards, he received the Nobel Prize in physics in 1993.

This picture was taken during the symposium with Joe Taylor's students and collaborators.

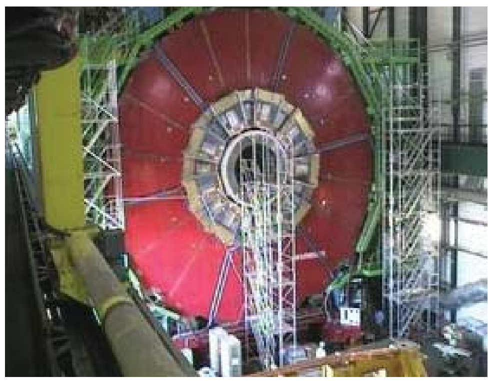
LHC: BEGINNING OF A NEW PARTICLE PHYSICS ERA?

Despite the striking success of the Standard Model (SM), there are many problems left to solve: the large hierarchy in energy scales, the presence of dark matter throughout the universe, and the origin of the many fundamental parameters. While we do not know yet what energy scale is relevant for the solution of these problems, the electroweak physics is pointing us to new phenomena at the TeV scale.

The most direct experimental path to these new phenomena requires stretching the capabilities of state of the art accelerators. Following this path, Princeton High Energy physicists are working on the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider at CERN. The Large Hadron Collider (LHC) is a particle accelerator that will probe deeper into matter than ever before. Due to come online in 2007, ultimately it will collide beams of protons at an energy of 14 TeV. Beams of lead nuclei will be also accelerated, smashing together at a collision energy of 1150 TeV. LHC will have the highest energy and the most intense beams in the world.

The LHC is being built in the same tunnel as CERN's Large Electron Positron collider, (LEP). Proton beams will be prepared by CERN's existing accelerator chain before being injected into the LHC. The LHC accelerator will be the largest superconducting installation in the world. In order to keep the LHC's beams on track in the CERN accelerator, superconducting magnets (cooled by liquid helium) will generate the strongest magnetic fields ever used.

Assembly of HF wedge 1



Muon Chamber installation in CMS construction hall at point 5, Cessy, France

Five experiments,(CMS, ATLAS, LHCb, ALICE, TOTEM) will study what happens when the LHC beams collide. The proton beams will cross each other 40 million times per second. At the highest beam intensities there will be roughly 25 proton-proton collisions for each crossing. Collisions will happen so frequently, that particles from one collision will still be traveling through the detector when the next collision occurs. This presents a formidable new challenge to the trigger system, which needs to select efficiently the interesting events. Understanding what happens in these collisions is the key to the LHC's success.

Among the responsibilities of Princeton's team are the measurement and delivery of the luminosity to CMS. The real time LHC performance and the overall normalization to the physics analyses will be provided by these luminosity measurements based on the forward hadronic calorimeter (HF).

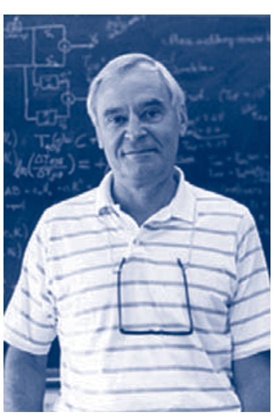
LHC physics is attracting not only the experimentalists but also the theorists at Princeton. The latter are preparing to establish a correspondence between theoretical models and experimental signatures while developing more efficient methods for recognizing novel physics.

All in the high energy community acknowledge the enormous discovery potential of LHC and hope to observe new, unforeseen phenomena. We are likely to be at the edge of a revolutionary time in the physics of fundamental particles.

Contributed by assistant professor Valerie Halyo

PEOPLE AND NEWS-continued

COBE



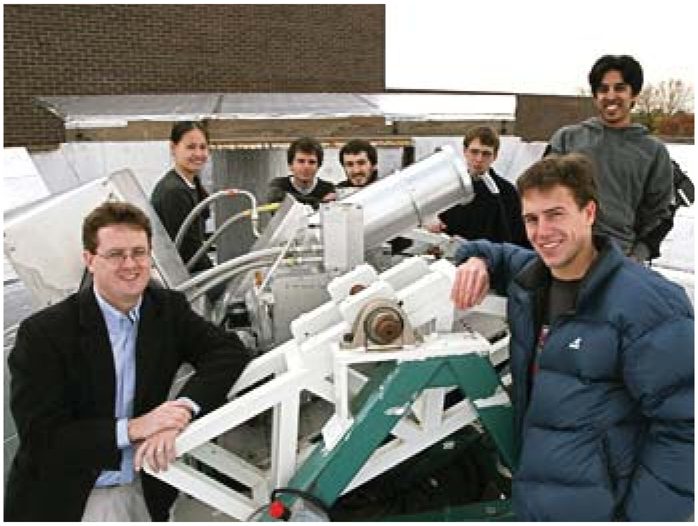
The Cosmic Microwave Background Explorer (COBE) satellite science team was awarded the Cosmology Prize of the Peter Gruber Foundation in August 2006. John Mather and George Smoot, two leaders of the COBE science team, were awarded the Nobel Prize in physics on October 6 , 2006.

Princeton's **David T. Wilkinson** (1935 –2002) was one of COBE's originators and one of the key scientists who guided the project through several scientific discoveries that are now cornerstones of physical cosmology.

The idea of COBE emerged in 1974 when Dave and fellow cosmologists met in New York City. Their goal was to study properties of the cosmic microwave background (CMB) and mm-wave emission from the Milky Way and distant galaxies. The satellite was launched in 1989, and in 1990 the science team announced the spectrum of the afterglow from the Big Bang to be that of a black body to within 1 percent, the limits of the measurement. Most view this as incontrovertible evidence for the hot Big Bang model of the universe. In 1992 the team announced the discovery of the anisotropy, or spatial variations, in the CMB. These ripples are produced by quantum fluctuations in the early universe. In 2003, the COBE anisotropy measurements were confirmed with stunning precision by the Wilkinson Microwave Anisotropy Probe (WMAP), posthumously named after Dave, its originator.

Dave was a pioneer in experimental cosmology and a dedicated teacher. COBE's success was rooted in the vast experience that its founders had in making measurements from balloons and ground-based experiments. The techniques Dave developed (for measuring both the absolute temperature and anisotropy of the CMB) and the students he taught have had an enormous impact on cosmology.

GRADUATE STUDENT LIFE—HOME ON THE RANGE



Joseph Fowler, assistant professor of physics, and graduate students test components of the Atacama Cosmology Telescope on the roof of Jadwin.

View from the ACT receiver cabin of the rail yard and crane.

The ACT telescope in Vancouver. The structure on the right side holds the 6m primary; inner ground screen, and elevation screws are also visible.

The Atacama Cosmology Telescope (ACT) is designed to measure the cosmic microwave background (CMB) on small scales, and is destined for the Atacama Desert of northern Chile. In the meantime, though, ACT lives in suburban Vancouver on a concrete pad in a steel yard. Working on ACT is one of the unpredictable adventures of graduate school. Many of us who work with Joe Fowler, Lyman Page, and Suzanne Staggs flew out to the AMEC yard this summer, stopping along the way to get work boots and at the local Tim Horton's for coffee before entering through AMEC's barbed-wire gate. You can see just how unlike Princeton this is in the photos to the left.

The ACT collaboration contracted AMEC Dynamic Systems of Port Coquitlam, British Columbia, to organize and build the telescope body, mirror panels, and motion control systems. Our goal was to integrate a prototype camera with their telescope systems and anticipate issues that might appear in Chile. It was a great time to get to know one another, meet others from the collaboration, and explore the psychology of working in shipping containers. Once the telescope and its systems operate to specification, it will be disassembled and shipped on a freight boat to Chile. That is exciting!

With ACT, we plan to study the Sunyaev-Zeldovich effect, which makes astronomical clusters visible by the distinct electron scattering signature they leave on the CMB photons. Because the clusters are 'backlit' by the CMB, the telescope will open a new view of the organization of matter in the universe. Also, measurements of the primary CMB will place better constraints on physics from the inflationary period of the early universe up to the epoch of recombination, as neutral atoms form and the CMB photons are liberated. The work in many ways will be a follow-up to WMAP's measurements (a CMB satellite also strongly tied to Princeton researchers), but on smaller scales. ACT is part of a constellation of coordinated observations with new and existing telescopes. This will connect the measured CMB radiation in the ACT study to fields in different bands, and provide a wealth of astronomical data that single surveys cannot obtain.

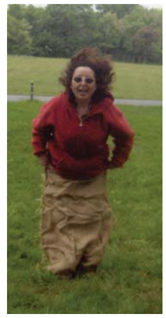
Cosmology at Princeton is a comfortable, close-knit community. Graduate students are able to pursue a broad range of research, from the nuts and bolts of instrumentation to connections between string theory and physics of the early universe, and to exchange ideas through the larger "Gravity Group" at Princeton. The Gravity Group presents weekly findings by either cosmology graduate students or young researchers worldwide.

Contributed by graduate student Eric Switzer

ACT is a collaboration between groups at the University of British Columbia, Cardiff University, Columbia University, University of Pennsylvania, Princeton University, Lawrence Livermore National Labs, NASA Goddard, NIST, and the University of Toronto. Science collaborators include Rutgers University, University of KwaZulu-Natal (South Africa), Catolica University (Chile), INAOE (Mexico), University of Massachusetts, Haverford College, and the University of Pittsburgh. There are also project-wide educational efforts with links to York College and the City College of New York.

DEPARTMENTAL LIFE





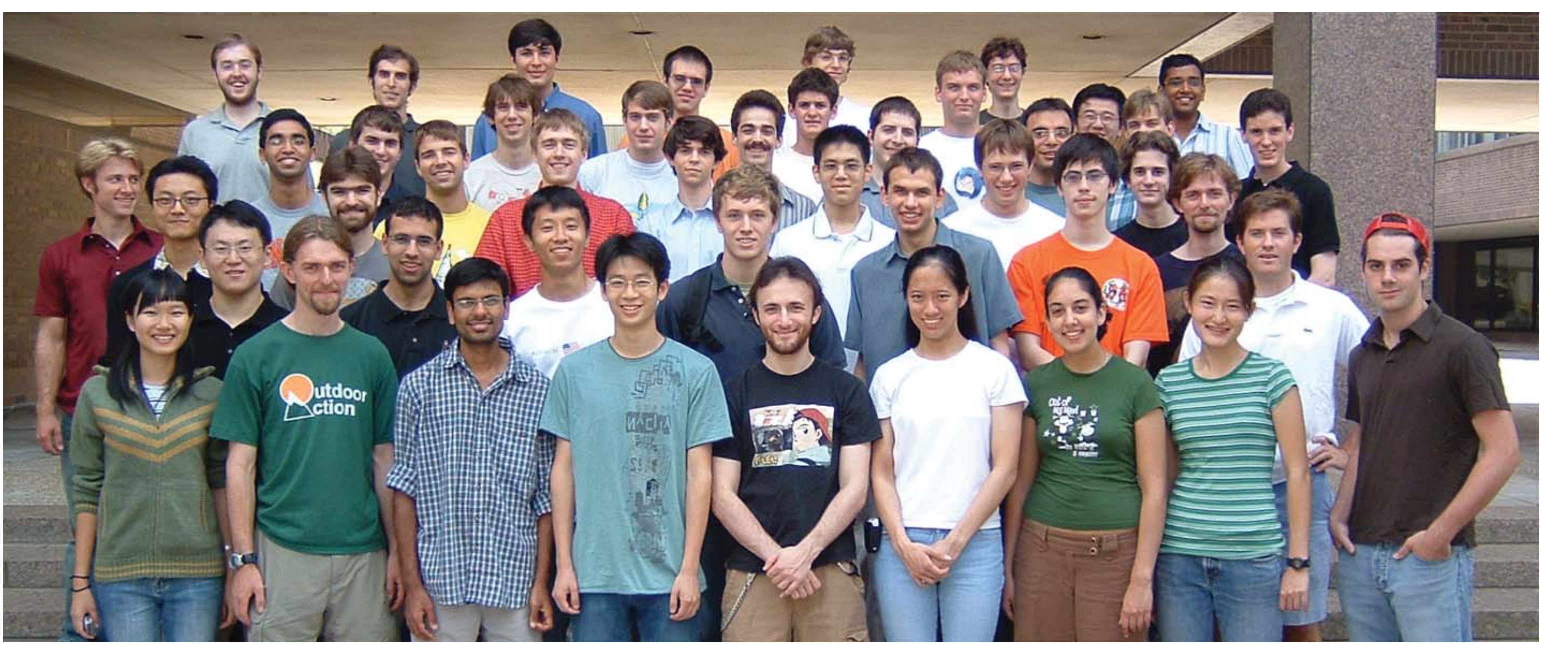
As the joke goes, physicists are too focused on their work to have much of a life. Princeton physicists are probably no exception. Nonetheless, the careful observer can uncover various instances of “departmental life” that very much contribute the culture of the place.

The annual music recital is certainly one of them. It started on one autumn day in 1988 when Laurel Lerner, pianist and graduate program administrator in the physics department, and two graduate students were talking over lunch about there being so much talent among the members of the department. They joked about how much fun it would be to have a talent show. After having a good laugh, they realized that it could be a reality. Over the years, with the help of Eva Zeisky, pianist and web administrator, the recital expanded from a “talent show” to a concert in the Taplin Auditorium, where faculty, staff, and students come together to perform and attend a wonderful event year after year. In recent years, the event included an art exhibit at the reception following the performances. This year the recital was held in memory of Professor George Reynolds, one of the first performers in this annual event. In the picture (above left), Professor Steve Gubser performs at the piano.

The biennial bike ride along the Delaware-Raritan Canal, organized twice a year by professor Ed Groth, attracts faculty, staff, and graduate students (pictured above). The “almost summer” bike ride is approximately 30 miles, the “fall colors” ride is 45 miles. In both cases, the highlight is a lunch stop at a restaurant along the canal, with free beer offered by Professor Groth to all participants over 21. In the picture (above, second left), graduate student Jackson Mayo 2005 offers his wishes to the riders, “Go Princeton ‘Almost Summer’ Bike Ride.”

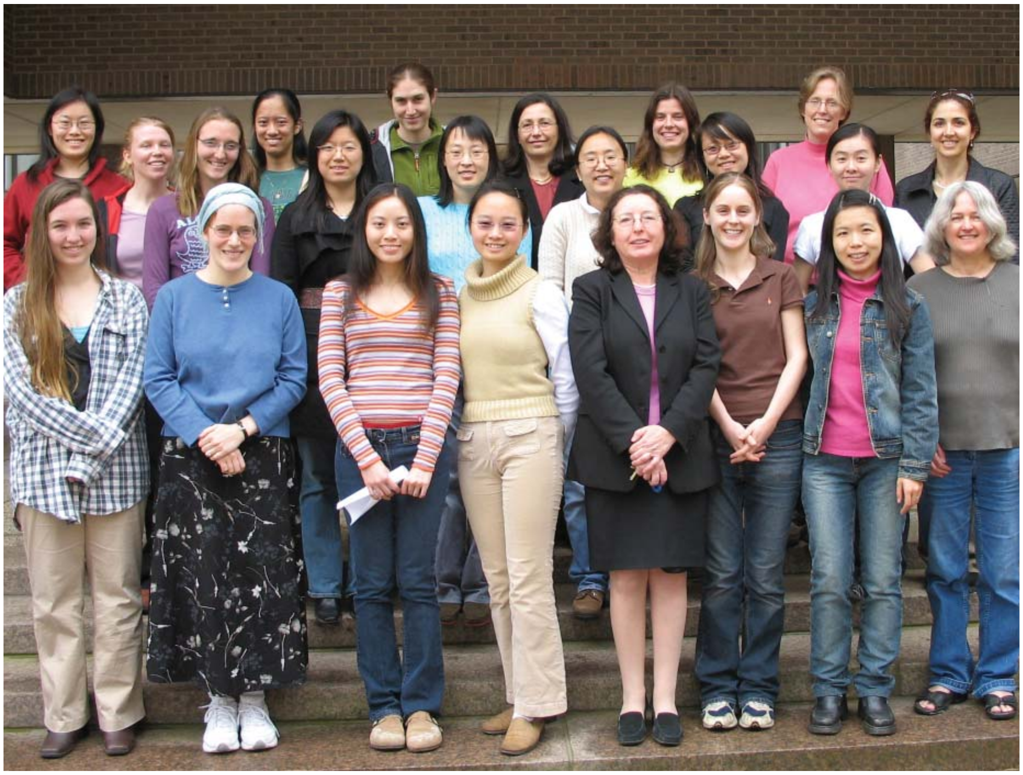
Thanks to the dedication of staff volunteers, great department traditions live on. The annual picnic in May is a family favorite, with pony rides for the little ones, sport challenges and socializing for the older ones, and lots of food for everyone. Traditionally, a sport competition (which the faculty always manages to win) takes place between a faculty team and a student team. In the picture above, Professor Nappi is competing in the sack race. Another cherished event is the holiday party. Department manager Paul Lamarche (above), whether in disguise or not, is always a favorite among the children.

The latest addition to “departmental life” is the physics fall trip. Over the fall break, students enrolled in the sophomore physics classes visit academic institutions in Southern California. The goal of the trip is for the students to get a first-hand experience of the physics of central force motion they learn in the classroom, and to make a direct connection with current research in planetary physics and cosmology. In the photo above and to the right, students march toward Palomar Observatory.



Physics juniors and seniors, fall 2006

WOMEN IN PHYSICS



WOMEN IN PHYSICS

A couple of times during the academic year women physicists at Princeton gather to discuss informally their research. This picture was taken during the spring 2006 meeting. The group includes junior and senior faculty, postdoctoral fellows, and graduate students.

First row, from left to right: Annika Peter, Rachel Mandelbaum, Shuang Lim, Yufang Wang, Chiara Nappi, Monica Skoge, Weining Man, Gillian Knapp

Second row: Fiona Burnell, Beth Reid, Liang Li, Yan Mei Wang, Minhyea Lee, Sophie Liu, Tao Long

Third row: Fei Gong, Mira Guo, Kathie Mack, Annabella Selloni, Sylvia Smullin, Suzanne Staggs, Valerie Halyo

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Princeton Physics News is a publication of the Princeton University Department of Physics
P. O. Box 708, Princeton, NJ 08542 e-mail: PHYnews@princeton.edu Web site: http://physics.princeton.edu/