THE PHYSICS MAJOR

DEPARTMENT OF PHYSICS AND ASTRONOMY

DARTMOUTH COLLEGE

September 2013
The Department of Physics and Astronomy website:
http: //www.dartmouth.edu/~physics

Upcoming colloquia and seminars:
http://www.dartmouth.edu/~physics/news/calendar.html

Organization, Regulations, and Courses:

If you are thinking of majoring in physics or engineering physics, and have any questions, please contact the department undergraduate adviser:

Professor Kristina Lynch
303A Wilder Laboratory
Phone: 646-9311
Email: Kristina.A.Lynch@dartmouth.edu

Cover photos:  (Upper right)  Array of Dartmouth Radio Receivers at Toolik Lake on the north slope, Alaska. Several physics professors, together with students, perform experiments in remote locations, investigating phenomena such as aurora or lightning.  (Left) Experimenters in Wilder Laboratory. Several physics professors, together with students, explore astonishing effects of quantum physics and the transition between quantum and classical physics.  (Lower right) Scientific sounding rocket [photo courtesy of NASA]. Several physics professors, together with students, participate in NASA rocket or balloon experiments.

Not pictured: Several physics professors, together with students
•perform theoretical and experimental investigations into quantum information science, a hot topic leading towards development of quantum computation.
•work on central problems in cosmology such as the origin of the universe and the nature of dark matter and dark energy.
•study the solar system space environment, including the Van Allen Radiation Belts and their adverse effects on spacecraft and astronauts.
•make theoretical or experimental investigations of confined charged particle gases, some with application to development of nuclear fusion as an energy source.
•research many topics in astronomy; see the pamphlet “The Astronomy major at Dartmouth College” for details.
Introduction

Physics has been defined as the study of that part of nature, which can be understood in mathematical terms. Physicists use mathematics to help them comprehend the enormous complexity of the world: to them, as to Galileo, "mathematics is the language of nature." As our knowledge of the physical world becomes deeper, more of it becomes amenable to mathematical formulation, and hence part of physics: for example, atoms used to be regarded as the domain of the chemist alone, while now atomic physics is at the core of the physics curriculum. Mathematics also advances, and becomes able to tackle problems previously thought to be beyond its scope. The great physicist Richard Feynman said in 1963 that he could not conceive of a mathematical description of a cloud, but at that very moment Benoit Mandelbrot was developing the mathematics of "fractals," which turned out to provide just that description. As a result, new branches of physics, such as condensed matter physics and non-linear dynamics, are continually coming into being, as are hybrids with other sciences, for example, chemical physics, geophysics, biophysics and psychophysics.

It has been truly said that without chemistry there would be no life: but without physics there would not be anything at all. The first half of this century saw a revolution in physics, in which "classical" physics, which reigned supreme at the turn of the century, was replaced in the domain of the very large by relativity and in that of the very small by quantum theory. This revolution was comparable in its philosophical implications to the great scientific revolution of the 17th Century (also, primarily, the work of physicists and astronomers). However, just as the latter did not significantly affect the consciousness of the general educated public until the following century, so the profound changes in our view of the world that this century's revolution requires, though the subject of much popular writing, have yet to be fully assimilated. Physics is not just a branch of technology but is one of the humanities, in the sense that its study is one road towards an understanding of our place in the Universe. This may be one reason why so many leaders in the struggle for freedom of thought in recent history have been physicists: Albert Einstein, Andrei Sakharov, Edward Condon, Yuri Orlov, Irina Ratushinskaya and Fang Lizhi, for example.

The physics major and your career

What do students of physics do when they have obtained the bachelor's degree? About 40% of our graduating majors go on to graduate study in physics or a related discipline, aiming at a career in academia or research. Others go to medical school or engineering school, some become high school science teachers, and others start work immediately as research technicians. However, by no means do all our majors pursue technical careers: there are many other possibilities. Many go into business, law school, social work and a host of other careers. Because physics is "the most fundamental and all-inclusive of the sciences" (Feynman), a physics or modified physics degree is a good basis for any career in which scientific and technological considerations play an important role: in the modern world, this includes almost the entire spectrum of human activity. The study of physics provides training in problem solving by quantitative and logical thinking and by model building, and develops the habit of concentrating on essentials and eliminating irrelevant detail. These are valuable skills in every walk of life. Many analytical techniques used in business and economics, such as operational research and game theory, were originally developed by physicists.
The physics major: prerequisites, required and recommended courses

By its very nature, physics requires a strong mathematical background, and the physics major has a minimum mathematical prerequisite of the four-course Introductory Calculus sequence ending with Differential Equations (Math 3, 8, 13, 23, or equivalent). Many students come to Dartmouth with advanced placement in mathematics and place out of one or more of these courses. While some of these courses can be taken in parallel with the introductory physics courses (numbered 13, 14, 19 and 24 or the honors sequence 15, 16, and 24), the minimum mathematical prerequisite must be satisfied before the core (40's level) physics courses are taken. More mathematics than this minimum is desirable, particularly for those interested in pursuing theoretical research in graduate school. Linear Algebra (Math 22 or 24) and Functions of a Complex Variable (Math 43) are particularly recommended, as is an introductory computing course such as CompSci 1 or Engineering 20.

First year students who achieve the levels described in Your First Year receive credit for Physics 3 and/or Physics 4. If their high school physics was at the level of Physics 13 or 14, they can earn credit for Physics 13 or 14 by taking the Physics 13 credit exam, offered during orientation week, or the Physics 14 credit exam, offered during the first few weeks of Fall term by arrangement with the Physics Advanced Placement Committee. (In Fall, 2013, the Chair of this committee is Professor Barrett Rogers.) These credit exams consist of 4-5 worked problems and require 2-3 hours to complete.

Another alternative for qualified students is to take the honors sequence, Physics 15-16, in place of Physics 13-14-19. This alternative is intended for students whose high school physics was nearly at the level of Physics 13. To take the honors sequence, students must take the Physics 15 placement exam, offered during orientation week and usually also by arrangement with the Physics 15 professor during the first few days of Fall term. (In Fall 2013, Physics 15 will be taught by Professor Robyn Millan.) The Physics 15 placement exam consists of about 30 multiple choice questions and requires less than an hour to complete.

The minimum physics major (including the physics prerequisites) consists of the following courses: Physics 13 and 14 (or 15 and 16), plus eight further courses. These must include Physics 19, 24, 41, 42, 43, 44. Beyond this core there are either two or three electives required, depending on whether Physics 19 was taken. One of the electives must fulfill the culminating experience requirement (see below). The major requires one upper-level laboratory course; Physics 47, Physics 48, Physics 76 or Astronomy 61. Elective courses are Physics 30, Physics 47, Physics 48, Astronomy 15 or 25, and all physics and astronomy courses numbered in the sixties, seventies and nineties. Courses in other departments (principally engineering or chemistry) can be substituted for some of these, by permission of the Chair. The core sequence (41-44) can be taken in any order. Students are required to complete a culminating activity in the major. For the physics major this requirement may be satisfied by receiving credit for one of the following courses: Physics 68, Physics 72, Physics 73, Physics 74, Physics 76, Physics 77, Physics 82, Physics 87, Astronomy 74, Astronomy 75, or Astronomy 81. Students who intend to proceed to graduate work in physics are strongly recommended to take more than the minimum number of electives. They should take Physics 66, 76, 91 and a selection of courses in the various subfields of physics (Physics 47, 68, 72 or 73), or in engineering, chemistry or another science department, depending upon their interests. There is also a wide range of graduate courses open to qualified undergraduates.

While it is desirable to begin the physics sequence in the first year, it is possible to begin in the sophomore year and still complete the minimum major within four years. Consult the Chair or major adviser at once if you are thinking of doing this
Modified Majors

Students with a wide range of interests, or who are particularly interested in cross-disciplinary fields such as biophysics, are encouraged to take a modified major, a double major, or a physics major with a minor in another subject. A modified major requires at least ten courses, of which at least six (excluding the two prerequisites) should be in physics. It is discussed in more detail in the next section. Another option is the Engineering Physics Major, which is described on page 6.

Students majoring in another subject may modify it with physics, or take a physics minor (see below). All courses numbered Physics 19 and above, or Astronomy 15 and above, are in principle suitable for the modified major, as long as the prerequisites are satisfied. It is often possible to substitute a course from another department for a prerequisite: for example EngSci 23 may substitute for Physics 41. Other substitutions can be made with the permission of the instructor of the course for which the prerequisite is required.

A modified major must be approved by the Registrar and must satisfy the requirements given in the ORC. The most important requirement is that the major be "planned as a unified, coherent whole." To ensure this, the student is required to provide a written rationale of the intellectual coherence of the proposed program, which must be approved by the major adviser (or other representative) of both departments involved.

Undergraduate Research Opportunities

The Physics and Astronomy department provides many opportunities for undergraduate research internships within the department's varied research programs. Most opportunities are jobs, typically 10 hours/week during class terms. The faculty encourages students to take advantage of these opportunities as soon as possible, starting in their first year and working toward Presidential Scholarship projects (http://www.dartmouth.edu/~ugar/undergrad/scholars) in their junior year, and senior theses in their last year. The research provides a valuable counterpart to coursework in learning about physics. We do not maintain a listing of opportunities, but prefer that you seek them out: ask your professor or approach a faculty member who is doing something you think is interesting. There is a list of senior theses submitted for honors in the past few years on pages 10 and 11 of this guide. The Women in Science Project (http://www.dartmouth.edu/~wisp/) is also a valuable resource.

Sarah Pasternak ’14 in Prof. Ramanathan’s Lab. (photo courtesy of Chandrasekhar Ramanathan)
The Dartmouth Physics Society

Congratulations, physics major, and welcome to the club! Of all the majors here, we'll wager that physics is the coolest one by far.

And whether you're a theorist or experiments are your style there's a place in Wilder where you can come and hang out for a while.

It's called "the Cave", it's in Room 9: Just go downstairs, turn left, then right. It's got a TV, Xbox, Wi, and fridge: It's home to DPS, it's where the undergrads all chill!

And if you like it there, then join! We hold events a couple times each term. Sometimes we bowl, sometimes we camp, we've gone to a theme park before: you can't beat that!

If all this sounds like fun, then blitz the email at the end of this. We'd love to meet you, so come on by - The DPS wants you! We'll see you in Room 9.

-Dartmouth Physics Society
dartmouth.physics.society@dartmouth.edu

(photos courtesy of Nina Maksimova '14)

The Physics Minor

The Physics Minor has the following course requirements:

*Prerequisites:* Mathematics 3, 8, 13, 23 or equivalents; Physics 13 and 14 (or 3 and 4, or 15 and 16). Four courses are required in addition to the prerequisites. One of these must be Physics 19, except students taking Physics 15 may substitute a fourth elective for Physics 19. The other three must be chosen from physics courses numbered 24 and above, and/or astronomy courses numbered 15 and above, at least one of which must be numbered above 40.

Mathematical Physics Minor

This minor is sponsored by the faculty in Mathematics and Physics. It may be combined with majors in either of the two departments, or any other department. Students majoring in both physics and math cannot take the minor.

*Prerequisites:* Physics 13, 14, 19 (or Physics 15 and 16), and Physics 24, Mathematics 3, 8, 13, and 22 or 24.
Requirements: A total of four additional courses are required. These must include Math 23 and Math 46. Math majors must choose two elective physics courses from the following list; physics majors must choose two elective math courses; students majoring in a department other than math or physics must choose one math and one physics course.

Physics 41, 42, 43, 44, 47, 66, 72, 75, 77, 91
Math 31 or 71, 63, 42, 43, 53, 54, 66, 73, 76

An advanced undergraduate or graduate level physics or math course may be substituted, with permission from the physics or math department undergraduate advisor. No course may count towards both the major and minor.

The Astronomy Major and Minor

A guide to the Astronomy major and minor is available from the Physics and Astronomy departmental office or at the department’s website.
http://www.dartmouth.edu/~physics/academics/undergraduate/astronomy/major.html

Suggested Enrollment Patterns for Physics Majors

The following are suggested course enrollment patterns for the sophomore through senior years. The first pattern is for students taking Physics 13 and 14 in their first year, while the second is for students who complete Physics 15, 16 and 24 in their first year. A good senior year sampling of graduate school preparatory and research related offerings is provided by Physics 76 (advanced lab), Physics 68 (Introductory Plasma Physics), Physics 72 (Introductory Particle Physics), and Physics 73 (Introductory Condensed Matter). Students choosing to do an honors thesis for their culminating experience may wish to take relevant research area courses in their junior year, eg. Physics 68, Physics 73 or appropriate Astronomy courses. Students who go quickly through 60s -70s -90s course offerings may choose to take graduate level courses in their senior year.

Physics 13, 14, 19, 24 pattern: EXAMPLE

<table>
<thead>
<tr>
<th>F</th>
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<th>S</th>
<th>X</th>
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<tr>
<td>Year 2</td>
<td>19</td>
<td>24</td>
<td>44, 24</td>
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<tr>
<td>Year 3</td>
<td>43, 47</td>
<td>41</td>
<td>66, 44</td>
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<tr>
<td>Year 4</td>
<td>68, 73</td>
<td>91</td>
<td>72, 74, 75, 76</td>
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Physics 15, 16, 24 pattern: EXAMPLE

<table>
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<th>F</th>
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<tbody>
<tr>
<td>Year 2</td>
<td>43</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>Year 3</td>
<td>47, 68</td>
<td>48</td>
<td>66</td>
</tr>
<tr>
<td>Year 4</td>
<td>68, 73</td>
<td>91</td>
<td>72, 74, 75, 76</td>
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The Engineering Physics Major

The Department of Engineering Sciences and the Department of Physics and Astronomy offer a major in Engineering Physics. This major features a 5/5 split in courses, unlike a modified major which requires six courses from one field and four from the other.

The prerequisites for this program are:

Math 3, 8, 13, 23; Phys 13, 14; Chem 5; and CoSc 1 and 10 or Engs 20

The required or core courses for this program are:

Engs 22 (Systems), 23 (Distributed Systems and Fields), 24 (Science of Materials) and Phys 19 (Introductory Physics III), 24 (Quantum Physics of Matter: An Introduction), 43 (Statistical Physics). [Students taking Physics 15 should substitute a fifth elective, which should be a physics course, for Physics 19.]

In addition, there are four electives--two from each department. You must select two electives from the following:

Engs 25 Introduction to Thermodynamics
Engs 33 Solid Mechanics
Engs 34 Fluid Mechanics
Phys 42 Introductory Quantum Mechanics
Phys 91 Intermediate Quantum Mechanics
Phys 73 Introductory Condensed Matter Physics or Engs 131 Science of Solid State Materials
Phys 66 Relativistic Electrodynamics or Engs 120 Electromagnetic Fields and Waves
Phys 44 Mechanics or Engs 140 Applied Mechanics: Dynamics

and any two electives* from the Engineering Sciences Department: Engs 21 and higher, excluding Engs80 and 87, or from the Physics and Astronomy Department which fulfill the straight Physics major.

A culminating experience is required in the major which can be taken instead of one of the electives above. It must be one of the following:

Phys 68 Introductory Plasma Physics
Phys 72 Introductory Particle Physics
Phys 73 Introductory Condensed Matter Physics
Phys 74 Space Plasma Physics
Phys 76 Methods of Experimental Physics
Phys 82 Special Topics Seminar
Phys 87 Undergraduate Research
Engs 86 Independent Project
Engs 88 Honors thesis
Engs 89** Engineering Design Methodology and Project Initiation [which must be taken as part of the two-course design sequence 89/90]

An advanced engineering sciences course with a significant design or research project, normally taken in the senior year, chosen from an approved list. (Consult the Engineering Sciences Department for the most recent list.)

**Prior to enrollment in Engineering Sciences 89 at least six engineering sciences courses must
be completed: Engineering Sciences 21 plus five additional courses numbered 22-76.

All major programs require an average GPA of 2.0 in all courses counted toward the major, including prerequisites.

For further information, please contact either

Professor Mary Hudson or Professor William Lotko
Physics and Astronomy Engineering Sciences

Faculty and Research Staff of the Department of Physics and Astronomy

Faculty

Stephon Alexander (Ph.D., Brown, 2000) Particles and fields, relativity and cosmology, quantum gravity, theoretical cosmology, early universe cosmology, large scale structure, string theory, loop quantum gravity, mathematics of music.


Robert Caldwell (Ph.D., University of Wisconsin, Milwaukee, 1992) Theoretical cosmology, gravitation, and relativistic astrophysics.

Brian Chaboyer (Ph.D., Yale University, 1993) Theoretical stellar astrophysics, formation of the Milky Way, globular cluster ages.


Marcelo Gleiser (Ph.D., University of London, 1986) Quantum and classical field theory, cosmology, and astrobiology.

Ryan Hickox (Ph.D. Harvard University, 2007) Active galactic nuclei, galaxy evolution, large-scale structure of the Universe, the cosmic X-ray background.

Mary Hudson (Ph.D., University of California, Los Angeles, 1974) Space plasma theory, plasma simulation; sun-earth connections, space weather, ring current plasma pause interaction, radiation belts, solar energetic particle trapping and effects of geomagnetic storms.

James LaBelle (Ph.D., Cornell University, 1985) Ionospheric and magnetospheric physics; plasma measurements in space; remote sensing of ionospheric plasma processes.

Kristina Lynch (Ph.D., University of New Hampshire, 1992) Ionospheric, auroral and mesospheric plasma physics; sounding rocket, CubeSat and laboratory plasma experiments.

Robyn Millan (Ph.D. University of California, Berkeley, 2002) Experimental space physics, radiation belt dynamics, lightning, hard X-ray/gamma ray observations and instrumentation.

Chandrasekhar Ramanathan (Sc.D., MIT, 1996) Experimental condensed matter physics and
quantum information science: electron and nuclear spin resonance, measurement and control of many-body spin dynamics, quantum devices and sensors.

Alexander Rimberg (Ph.D., Harvard University, 1992) Condensed matter experiment: electrical transport measurements of nanostructures such as quantum dots and single-electron transistors; quantum information science and quantum measurements; controlled physical realizations of open quantum systems; quantum noise and non-equilibrium effects.

Barrett Rogers (Ph.D., Massachusetts Institute of Technology, 1991) Theoretical and computational plasma physics.

Lorenza Viola (Ph.D., Padova, Italy, 1996) Theoretical quantum information science and quantum statistical mechanics: open quantum systems and quantum control, entanglement, quantum many-body systems, non-equilibrium dynamics, quantum chaos, topological phases of matter.

Gary Wegner (Ph.D., University of Washington, 1971) Cosmology, large-scale structure of the universe, end states of stellar evolution.

Kevin Wright (Ph.D., University of Rochester, 2009) Ultra-cold quantum gases, strongly correlated quantum matter, quantum information, neutral atoms in optical lattices and cavities.

Adjunct Faculty


Alain Brizard (Ph.D., Princeton University, 1990) Low-frequency nonlinear gyrokinetic theory, relativistic quasilinear transport driven by arbitrary-frequency electromagnetic fluctuations, variational formulations of exact and reduced, kinetic and fluid plasma equations, applications of Lie-transform methods in plasma physics.

Theodore Fulton (Ph.D., Cornell University, 1966) Condensed matter physics, particularly single-electron devices and Josephson effects.

Christopher Levey (Ph.D., University of Wisconsin, Madison, 1984) Microelectromechanical Systems (MEMS), micro and nanofabrication technology, solid state physics.

Jifeng Liu (Ph.D. MIT, 2006) Optoelectronic materials and devices; Nanophotonics for solar cells and concentrated solar power (CSP); Electronic-Photonic Integration.

William Lotko (Ph.D., University of California, Los Angeles, 1981) Space plasma physics, modeling, simulation; magnetohydrodynamics; geospace environment.

Robert Naumann (Ph.D. Princeton University, 1953) Nuclear structure and spectroscopy.

Brian Pogue (Ph.D., McMaster University, Canada, 1996) Medical physics, radiation therapy imaging and dosimetry, medical imaging systems, biomedical optics and imaging.

Timothy Smith (Ph.D. University of Massachusetts at Lowell, 1990) Experimental intermediate energy physics; the distribution of quarks in neutrons and protons.
Francesco Ticozzi (Ph.D. University of Padua, 2007) Quantum control, quantum information protection, stability theory, quantum communication.

Aleksandr Ukhorskiy (Ph.D., University of Maryland, 2003) Space physics.

John Weaver (Ph.D. University of Virginia, 1983) Medical Imaging, magnetic nanoparticle sensing and imaging, MRI, MR elastography, radiation dosimetry.

Postdoctoral Associates


Francesca Civano (Ph.D. Bologna, Italy, 2007) Active galactic nuclei, galaxy evolution, X-ray and multi-wavelength data analysis.


Kevin Hainline (Ph.D. University of California, Los Angeles, 2012) High-redshift galaxies, active galactic nuclei, optical spectroscopy and multi-wavelength data analysis.


Leslie Woodger (Ph.D. Dartmouth College, 2012) Experimental space physics and radiation belt dynamics.

### Senior theses offered recently in Physics and Astronomy

<table>
<thead>
<tr>
<th>Name</th>
<th>Title of Thesis</th>
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<tbody>
<tr>
<td>Nathan Monnig</td>
<td>A Proposal to Detect the Dynamical Casimir Effect Based Upon Absorption Spectroscopy of Lithium Atoms</td>
</tr>
<tr>
<td>Michael J. Holliday</td>
<td>Modeling Ionospheric Current Structures in Response to Sudden Impulse Events</td>
</tr>
<tr>
<td>Kelly Michaelson</td>
<td>Analysis of BLAST Events Involving Delta Formation, $\text{H}(e,e'\pi+n)$</td>
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<tr>
<td>Bart Butler</td>
<td>Environmental Effects on the Nonexponential Decay of Metastable Quantum States</td>
</tr>
<tr>
<td>Paul Durkee</td>
<td>Micro-Cantilevers: A Novel Approach to Observing the Mechanical Properties of Materials Undergoing Phase Transitions</td>
</tr>
<tr>
<td>Jonathan Huang</td>
<td>The Physics of Sheared Flows in Fusion Plasmas</td>
</tr>
<tr>
<td>Ryan Michney</td>
<td>Anisotropy in the Cosmic Neutrino Background</td>
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<tr>
<td>Sarah Taylor Smith</td>
<td>Nonequilibrium Phenomena in Open Classical Systems</td>
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<tr>
<td>Karsten Chu</td>
<td>Real-Time Detection of Electron Motion: Radio-Frequency Single Electron Transistor and Resonant Impedance Matching</td>
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<tr>
<td>Bibek Dhital</td>
<td>The Search for Naturally Existing Delta Baryons in Deuterium</td>
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<tr>
<td>Lance Labun</td>
<td>Stochastic Resonance and Measurement Back-Action in Non-Linear Oscillators</td>
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<td>Gwen Rudie</td>
<td>The Expansion Kinematics of the Remnants of Low-Mass, Core-Collapse Supernovae</td>
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<tr>
<td>Phillip J. Bracikowski</td>
<td>Study of Mesospheric Dust</td>
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<tr>
<td>Alexander B. Crew</td>
<td>Data Analysis of Magnetic Fields from ROPA Sounding Rocket</td>
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<tr>
<td>Parker Fagrelius</td>
<td>Understanding Quantum Mechanics: Entangling Our Reality</td>
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<tr>
<td>Brendan K. Huang</td>
<td>Investigation of Microscopic Photon and Phonon Quantum Non-Demolition Schemes</td>
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<tr>
<td>Leon N. Maurer</td>
<td>Low Temperature Coulomb Blockade Thermometer</td>
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<tr>
<td>Bennet E. Meyers</td>
<td>Spectral Analysis of X-Rays Produced in Lightning Stroke Events</td>
</tr>
<tr>
<td>David A. Strauss</td>
<td>VLF Propagation Study at 24kHz</td>
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</table>
Karl B. Yando  A Monte Carlo Simulation of the MEPED Particle Detector Module
Jordan A. Zastrow  An Optical Study of the Circumstellar Medium in Cassiopeia A
Benjamin Chapman  Nonlinear Effects in Oscillator Chains
Matthew Schenker  VLBI Mapping of H2O Megamasers in MRK 1419
Wendell Smith  The Entangled Twin Paradox
Steven Weber  Radio Frequency Quantum Point Contacts With On-Chip Inductors
Ian Boneysteele  Delta Pion Channels
Laura DeLorenzo  Nonlinear Dynamics of a DC Voltage Biased Microwave Cavity With an Embedded Josephson Junction
Ian Hayes  Microwave Resonators for the Study of the Quantum-To-Classical Transition
Umair Siddiqui  Design, Calibration and Use of a Collimated Electron Source for Plasma Sheath Studies
Dhrubo Jyoti  Dipolarly-Coupled Chaotic Quantum Spin Systems
John Roland  Fabrication of Nano-Mechanical Resonators for the Study of the Quantum to Classical Transition
Julianna Scheiman  Feasibility of Using POES Satellites and Riometers to Systematically Measure Relativistic Electron Precipitation
Emily DeBaun  Nonlinear Dynamics of a Biological Cell in a Uniform Electric Field
Amanda Slagle  Vector Field Mapping and Analysis Using Finite Sensor Swarms
Nicholas Knezek  An Analysis of Energetic Oxygen Interaction with Europe in the Jovian Magnetosphere
Michael Chilcote  Numerical and Experimental Investigations of Ionospheric Sounding Using AM Radio
Aryeh Drager  Using Multimedia Pre-Lecture Assignments to Improve the Introductory Physics Experience
Benjamin Katz  Special-Relativistic Effects of a Microscale Oscillator on a Macroscopic Quantum State
Alexander Meill  Measurement-Based Quantum Computing in Nuclear Magnetic Resonance