
2007-2008
Annual Report

# WOOSTER PHYSICS

Department of Physics
308 E University St
Wooster OH 44691

THE COLLEGE OF

# WOOSTER

## 12th Annual Report
## September 2008

Produced by Jackie S. Middleton

On the Front Cover:

· Mary Mills '09, Heather Moore '10, and Frank King '09 make a stop at Cleveland's Rock and Roll Hall of Fame during their giant slide rule road trip.
Photo by Henry Timmers '09

On the Back Cover:

· Kirsten Larson '08 and John Gamble '08 conduct an air pressure demo at a local elementary school.

· Henry Timmers '09 hams it up in "Theoretical Football" video.

· Ingrid Thvedt '11 explains her research at the NSF-REU summer poster session.

· The June 14 wedding of John Gamble '08 and Katherine Kelley '08:
Kirsten Larson '08, Kelly Patton '08, bride, groom, Dr. Lindner, Mark Wellons '08, Frank King '09.

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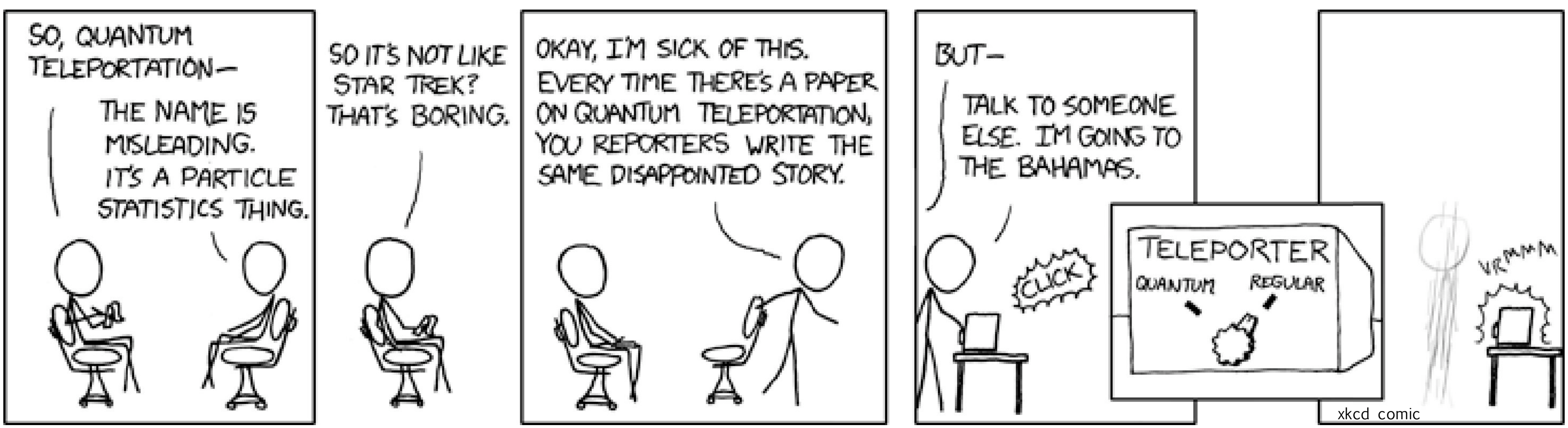


xkcd comic

# GREETINGS FROM THE CHAIR

Wooster Physics Alumni & Friends:

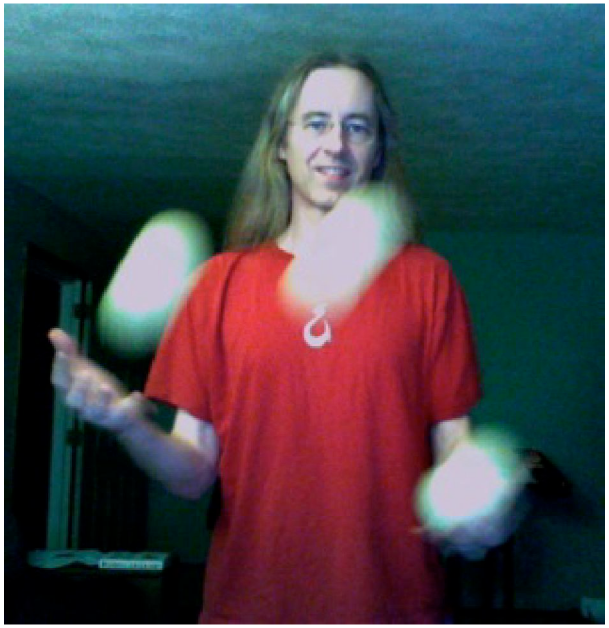
Welcome to the Twelfth Annual Report from The College of Wooster Department of Physics. We've had another exciting and eventful year.

After two years as visiting assistant professor of physics, Todd McAlpine accepted a position at Ohio Northern University. Todd has done a wonderful job here at Wooster, and we wish him well at ONU and beyond. Meanwhile, we welcome a new tenure-track professor of physics, Kristin Domike. Kristin has bachelor and masters degrees from MIT, and she has just completed her Ph.D. in physics from Cambridge University in the UK. Last year, Kristin was an adjunct instructor of physics, and taught a section of FYS and a new course, Physics 199: Physics of Biomaterials.

Our Physics Club vice-president Kelly Patton won the Notestein Prize for highest scholarship, while Physics Club president John Gamble spoke for the senior class at commencement. This marked the fourth time in eight years that physics majors have won the Notestein prize and spoken at commencement. John also became the fifth physics major in eight years to win an NSF graduate fellowship.

Congratulations to junior physics majors Martha Roseberry and Evan Heidtmann who last semeaster coauthored separate articles that were featured on the covers of two different physics journals. That doesn't happen very often!

We had another record breaking elementary school outreach program, with 13 different presentations. In addition, we obtained significant SGA funding to purchase more equipment to enhance and expand our demos. Six of us attended the March meeting of the American Physical Society in New Orleans. We presented four posters and enjoyed New Orleans sights, sounds, and cuisine. Our fourteenth annual NSF-REU program included students from NYU, Columbia University, the University of Portland, and Kenyon College.



Manon completed a great first year as our laboratory technician. This included the acquisition of all-new ergonomic computer chairs to replace the harsh metal stools in Taylor 101, our intro physics lab. Jackie has done another wonderful job overseeing the department and completing this annual report.

Please email or visit if you're in the area -- we love to hear how you are doing!

John Lindner
Czar of Physics

# FACULTY

Teaching:
Fall 2007
First Year Seminar: "Dr. Frankenstein, Dr. Strangelove, Mr. Spock and Doc Ock: Science and Technology, Good and Evil"
Modern Physics and lab

Spring 2008
Foundations of Physics 204 lab
Quantum Mechanics
Junior Independent Study

## Susan Lehman

Clare Boothe Luce Assistant Professor of Physics
B.A., Goshen 1993;
M.S., Ph.D. North Carolina Chapel Hill 1996;
at Wooster since 2003

*Riding a carousel with real ponies in Vienna, Austria.*

I really enjoyed teaching Modern Physics and its lab last fall for the first time. The Modern lab equipment is steadily being improved with a new Millikan Oil Drop experiment a few years ago and this year a new Rutherford Scattering experiment in which the students actually bombard a gold film with alpha particles. I've also been working to add an Optical Tweezers experiment to the Modern Physics repertoire, which should be fully completed this fall.

I worked with Joe Thomas for his senior IS project investigating the Mpemba Effect. We've found some interesting physics just by observing the temperature as water cools and freezes. It has been surprising to see how a project which started as a small idea in Junior IS has expanded with REU student Ingrid Thvedt working on the project this summer. We'll see what may happen with the self-designed projects of the great group of nine juniors this coming year!

My son William is now almost 2 1/2 years old, and he makes me laugh pretty much every day. It's been amazing to see how quickly he grows and develops language.

## John Lindner

The Moore Professor of Astronomy
Professor and Chair of Physics
B.S., Vermont 1982;
Ph.D. California Inst of Tech 1988;
at Wooster since 1988

Personal highlights of the last year include working with Kelly Patton & John Gamble on their senior theses. A big focus of my fall semester was my FYS, “Belief in God in an Age of Science”, a new course for which I created a twenty-two thousand-word blog (at http://www.wooster.edu/Physics/Lindner/FYS2007/blog.html). A major focus of my spring semester was “Computational Physics”, also a new course, for which I created all of the programming examples: (http://www.wooster.edu/Physics/Lindner/Ph377Spring2008/schedule.html).


*Albert Einstein offered Dr. Lindner some hair care advice on a recent visit to the Department.*

In January, I thoroughly enjoyed working with the Physics Club to create our award-winning video, “Theoretical Football” (http://www.wooster.edu/physics/SPS/TheoreticalFootball.html). In March, I accompanied four physics majors to a meeting of the American Physical Society in New Orleans, Louisiana, where Kelly & I coauthored a poster on the experimental observation of solitons in an array of one-way coupled oscillators. In the spring and fall, I gave invited talks at Marietta and Oberlin colleges on my work in modeling hair cells in the inner ear.

Martha Roseberry, Danny Shai, Nick Harmon, Katherine Olaksen, and I extended the reach of chaos in Newtonian physics with the paper “Precession and Chaos in the Classical Two-Body Problem in a Spherical Universe”, which was featured on the cover of the February 2008 issue of the International *Journal of Bifurcation and Chaos*. Lisa May Walker and Evan Heidtmann and I described an advance in practical computational physics with the paper “Invitation to embarrassingly parallel computing”, which was featured on the April/May 2008 cover of the *American Journal of Physics*.

Teaching:
Fall 2007
First Year Seminar: “Belief in God in an Age of Science”
Particle Physics

Spring 2008
Astronomy of Stars & Galaxies
Selected Topics - Computational Physics

In late May and early June, John Gamble and I wrote and submitted an article on quantum decoherence, inspired by his senior thesis. In late August, Kelly Patton and I submitted another article on one-way coupling, based in large part on her senior thesis. Meanwhile, Todd McAlpine, Corey Atwood-Stone, Travis Brown and I are completing an article on our celestial clock, which should be operational soon.

# FACULTY

The 2007-2008 academic year brought with it a number of firsts for me. In the Fall, I taught both Astronomy of Stars and Galaxies and Foundations of Physics and its accompanying labs for the first time ever! Additionally, I took on both Kirsten Larson and Mark Wellons as my very first two Senior IS students and also began working with Travis Brown (Geology) on the Celestial Clock (through Wooster's Sophomore Research Program).

*Dr. McAlpine is all wrapped up by his new dog Oliver.*

## Todd McAlpine

Visiting Assistant Professor of Physics
M.S., Ph.D. University of Kansas, 2003, 2006
B.S. Edinboro University of Pennsylvania, 2000

Teaching:
Fall 2007
Astronomy of Stars & Galaxies
Foundations of Physics 203 and labs

Spring 2008
Astronomy of Solar System
Foundations of Physics 204 and lab

In Spring 2008, after a harrowing weekend figuring out how to get about in a dozen feet of snow delivered by the blizzard that accompanied the beginning of spring break, I went to the American Physical Society March Meeting (also a first!) in New Orleans, LA with the Wooster group, where Frank King and Mark Wellons co-presented a poster on work they had done with me ("Simulating a Charged Spherical Pendulum in Time-Varying Electric and Magnetic Fields"). Thankfully, there was no snow in New Orleans.

In between all of this, I squeezed in a little time to hunt for a new job (alas, 'Visiting' positions only last so long) and was hired on as a one-year Visiting Assistant Professor of Physics at Ohio Northern University, 110 miles due west of Wooster in Ada, OH.

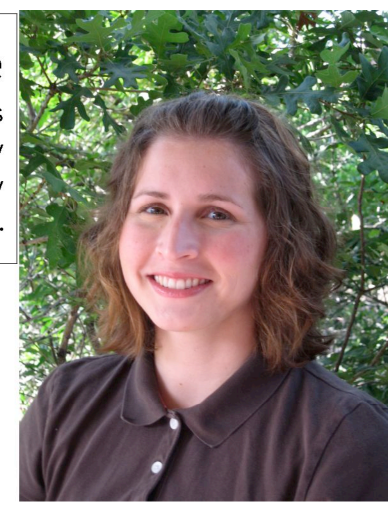
In Summer 2008, I worked with Wooster student Alison Huff to investigate some strange results that Mark Wellons found on the Charged Pendulum project. I also found an apartment in Ada, moved my massive collection of book and took a brief break while taking in my new surroundings, cooking Indian food, reading novels, riding my bicycle in circles around Hardin County, and taking my Shar-pei Oliver for long walks. I am finishing up the Celestial Clock, and contemplating the purchase of a good practice chanter so I can teach myself to play the bagpipes.

## Kristin Domike

Adjunct Instructor of Physics
B.S. 2003 Massachusetts Institute of Technology
M.E. 2004 Massachusetts Institute of Technology
Ph.D. 2008 University of Cambridge, U.K.

Teaching:
Fall 2007
First-Year Seminar: "So, You Want to Save the World, Now What?"

Spring 2008
Physics of Biomaterials



I completed my PhD in Physics at the University of Cambridge, England this year, successfully defending my PhD thesis entitled, "A Study of Large-Scale Aggregation Mechanisms and Kinetics of β-lactoglobulin Protein." I had two papers published this year, and I have submitted another based on a collaboration with the Wooster REU summer research program from summer 2007. I enjoyed teaching a new Biomaterials course in the College of Wooster Physics Department this spring 2008, and I am looking forward to joining the Physics Department full-time this coming year as an Assistant Professor.

# FACULTY

## Donald Jacobs

Victor J. Andrew Professor of Physics
B.A., M.A. University of South Florida 1971, 1972;
Ph.D. Colorado, 1976; at Wooster since 1976

Teaching:
Fall 2007
General Physics 101 and lab
Mechanics

Spring 2008
General Physics 102 and labs
Math Methods

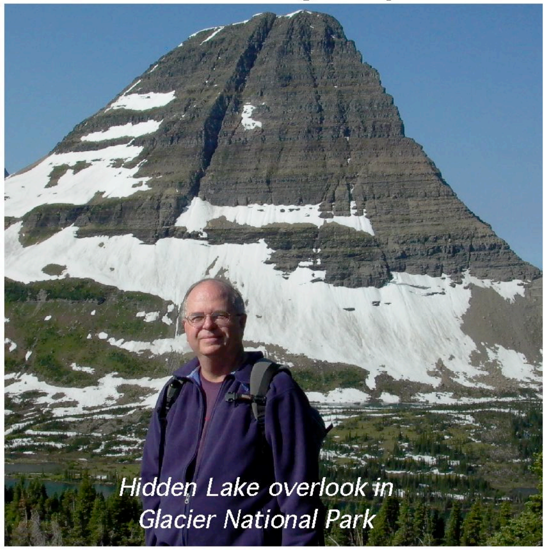
Dr. Jacobs had a busy and productive year. In General Physics, he developed a unit on the motion of paramecium as an application of biophysics. In the second semester of the course, he added two pedagogical changes. One was to use a sympodium with PowerPoint presentations he developed on each chapter to use as a review of concepts and to visually illustrate applications that could be annotated. The second was to periodically incorporate peer instruction techniques into the class. He directed two Senior Independent Study projects: a self-organized criticality project with Howard Henry and a percolation project with Mateo Chinchilla. During the summer, Dr. Jacobs directed research by two REU students and one Wooster post-graduate. In addition, Bryna Clover, a graduate student in chemistry at the University of Maryland, College Park, spent several weeks collaborating on a heat capacity experiment on block copolymers in D2O.

Dr. Jacobs submitted a successful grant proposal to Research Corporation titled "Cylindrical micelles from block copolymers: Self-assembly as an indirect model for biological systems" for $44,950 over a two-year period.

He went to two conferences this past summer: the Gordon Conference on Granular Materials and Granular Flow held at Colby College in Maine, and the Gordon Conference on Polymer Physics held at Salve Regina University in Rhode Island. Below are the titles and undergraduate co-authors of the presentations:

"Percolation via Electrical Conduction" by D.T. Jacobs, Mateo Chinchilla, Mark Zimmerman & Brad Thomas

"Universal scaling in near-critical, 8-arm star polystyrene + methylcyclohexane mixtures" by D. T. Jacobs, Andy Brinck, Adam Cohen, Mark Lightfoot, Christopher Locke, Sarah Suddendorf, Henry Timmers, Angie Triplett, Nithya Venkataraman and Mark Wellons



*Hidden Lake overlook in Glacier National Park*

## Shila Garg

Dean of the Faculty
William F. Harn Professor of Physics
B.S., Madras (India) 1970; M.S. Sussex (UK) 1972;
Ph.D. Kent (UK) 1975; at Wooster since 1984

# STAFF

## Manon Grugel-Watson

Laboratory Technician
since 2007

## Jackie Middleton

Adminstrative Coordinator
Departments of Physics, Math, & Computer Science
since 1989

# CLASS OF 2008

Mateo, Joe, Kirsten, Kelly, John, Howard, Mark

Mateo Chinchilla
North Olmsted OH
Employment: Product Engineer,
Venture Lighting Int'l, Solon OH

Joseph Thomas
St. Louis MO
Employment

Kirsten Larson
Mansfield OH
Graduate School:
University of Hawaii (astronomy)

Kelly Patton
Wooster OH
Graduate School:
North Carolina State (physics)

John Gamble
Erie PA
Graduate School:
University of Wisconsin, Madison (physics)

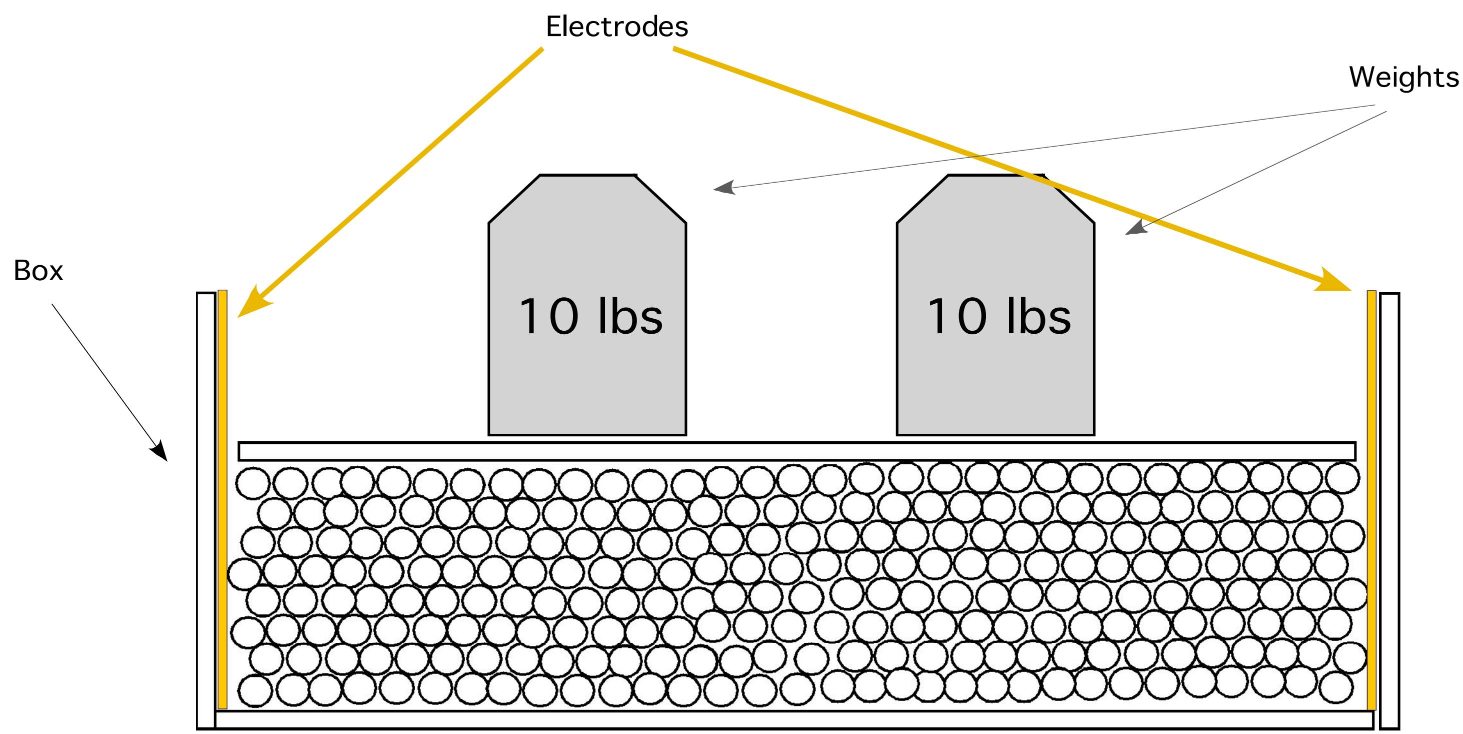
Howard Henry
Kingston, Jamaica
Employment: Software Support Specialist
McGraw-Hill, Columbus OH

Mark Wellons
Charleston WV
Employment

SENIOR INDEPENDENT STUDY

**Percolation via Electrical Induction**
by Mateo Chinchilla
Advised by Donald Jacobs

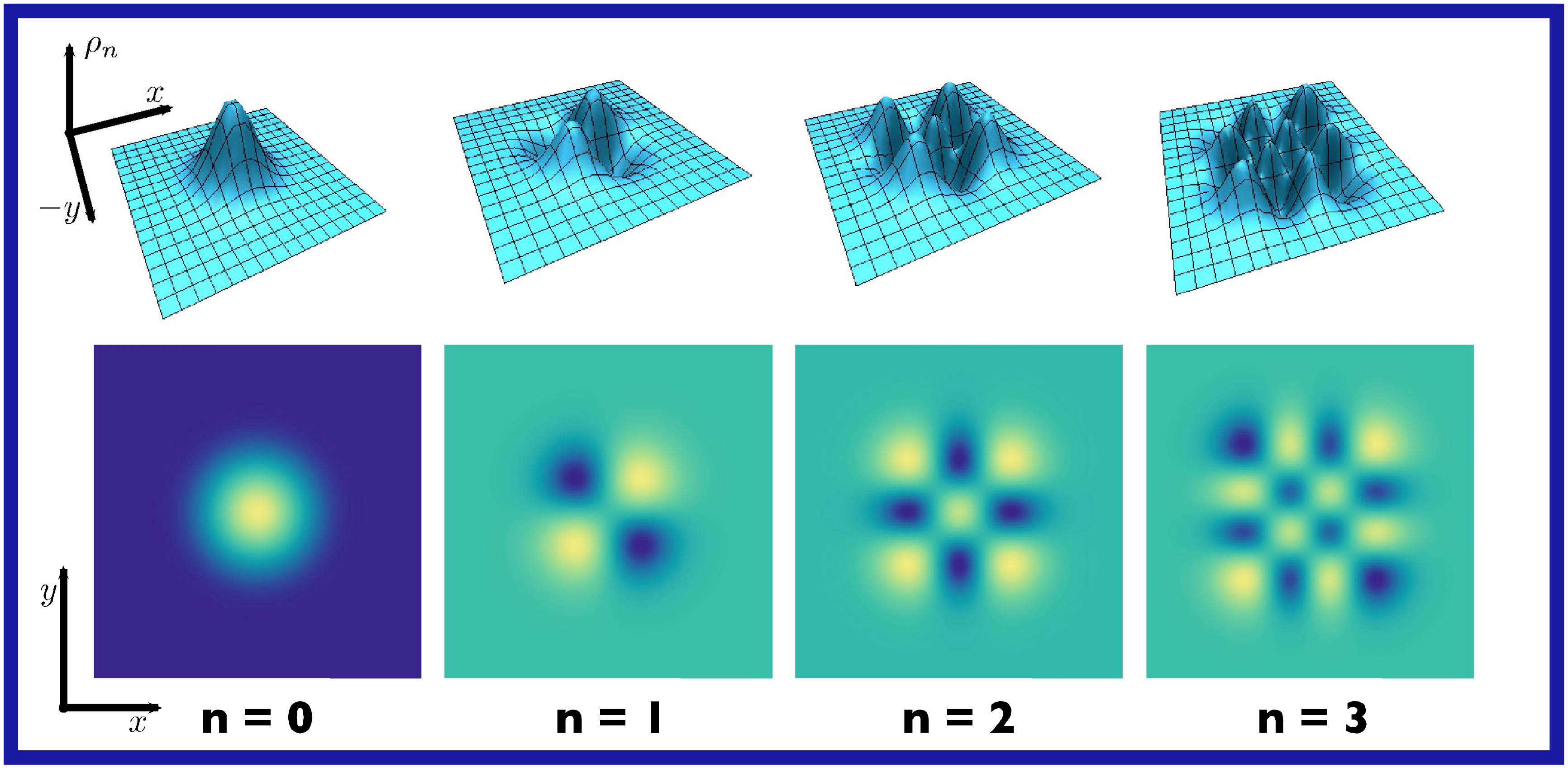
An experiment was conducted to study the ideas pertaining to percolation by observing the flow of electricity through a system of conducting and insulating spheres. Determinations of the percolation threshold $p_C$ were achieved by measuring the resistance of the system. Preliminary investigations were conducted to determine the effects of pressure, sphere organization and system settling on the resistance. The bulk of the experiment concentrated on measuring the percolation threshold of three different size systems by varying the number fraction of conducting spheres in the mixture of ~3 mm in diameter steel shot and glass spheres. Results have qualitative and quantitative similarities to published work done on comparable systems, both experimental and through simulations. A hyperbolic tangent function was used to extract the percolation threshold and steepness of the curve at the percolation threshold. The percolation threshold value obtained in the 15-layer system is $p_C$ = 0.719 and $p_C$ = 0.87 in the 4-layer system. A shift in the percolation threshold consistent with 2D to 3D modeling was observed as the system size increased. The varying system size also influenced the steepness of the curve. Using the work of Khanikaev et al, the small difference in sphere size between conducting and insulating spheres was determined to have a negligible effect on $p_C$. Finally, mean-field theories and a fit function proposed by Brouers were used to investigate bead geometry under pressure. The hyperbolic tangent function described the data better than the Brouers' function. It was concluded from the experimental data collected and its comparison to theoretical values that the percolation threshold observed is not representative of bond or site percolation, but rather a mixture of the two.



# SENIOR INDEPENDENT STUDY

**Foundations of Quantum Decoherence**
by John Gamble
Advised by John Lindner (Physics)
and Derek Newland (Math)

The conventional interpretation of quantum mechanics, though it permits a correspondence to classical physics, leaves the exact mechanism of transition unclear. Though this was only of philosophical importance throughout the twentieth century, over the past decade new technological developments, such as quantum computing, require a more thorough understanding of not just the *result* of quantum emergence, but also its *mechanism*. Quantum decoherence theory is the model that developed out of necessity to deal with the quantum-classical transition explicitly, and without external observers. In this thesis, we present a self-contained and rigorously argued full derivation of the master equation for quantum brownian motion, one of the key results in quantum decoherence theory. We accomplish this from a foundational perspective, only assuming a few basic axioms of quantum mechanics and deriving their consequences. We then consider a physical example of the master equation and show that quantum decoherence successfully represents the transition from a quantum to classical system.

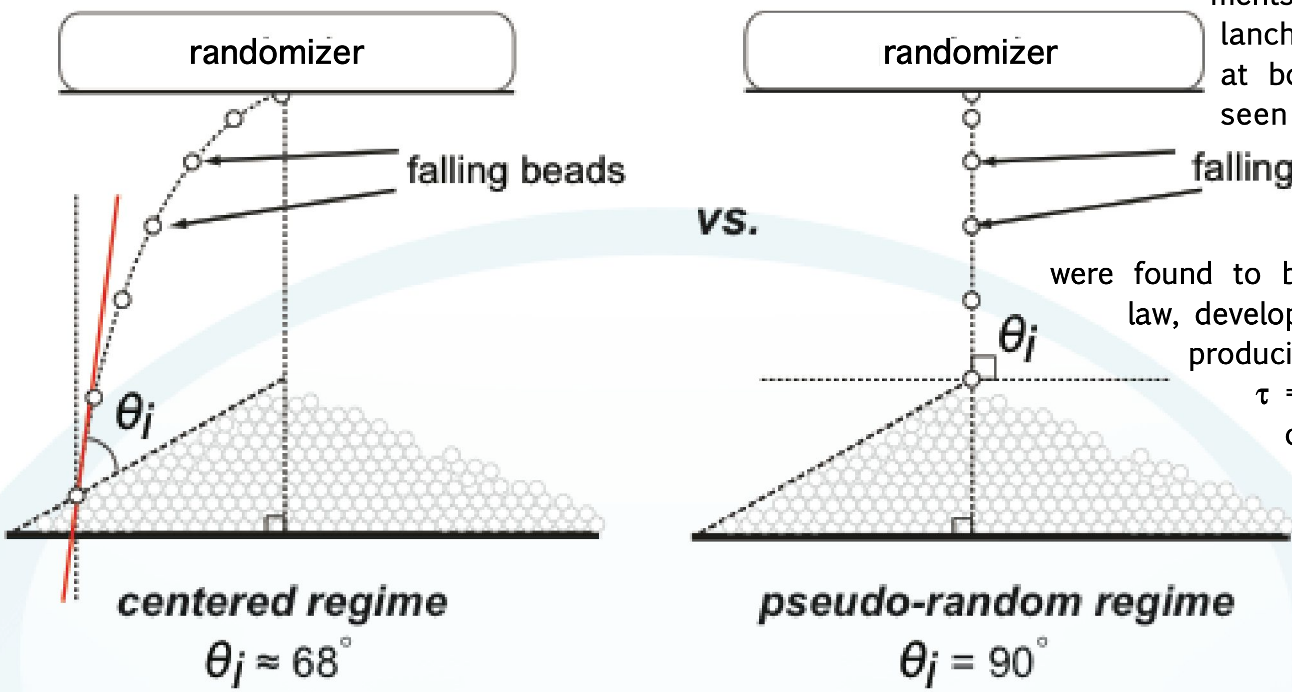


**Self-Organized Criticality:**
**An Investigation of Pseudo-Random Bead Drop Dynamics**

by Howard Henry
Advised by Donald Jacobs

In this experiment, I first tested the consistency of SOC using zirconium beads dropped onto the apex of a conical bead pile conducting two sets of data runs at two separate drop heights, 1.5 cm and 4.0 cm. SOC behavior was observed and was in fact completely consistent with mean field theory predictions. The resulting probability distribution of avalanche sizes *s* when the system was at a 1.5 cm drop height produced a pure power law with exponent of 1.50 ± 0.01, which is the mean field predicted value. The system's behavior deviated slightly from mean field values at the 4.0 cm drop height as I obtained a power law exponent of 1.69 ± 0.02, 13 percent greater than the mean field value.

The experiment was then modified from dropping beads onto the apex of the pile to a pseudo-random bead distribution of the beads onto the surface of the pile. Using similar drop heights of 1.0 cm and 4.0 cm as the previously conducted experiments, the probability distribution of avalanche sizes showed significant deviation at both heights from the pure power law seen in the centered drop experiments.




$\theta_i$ = impact angle with respect to the slope

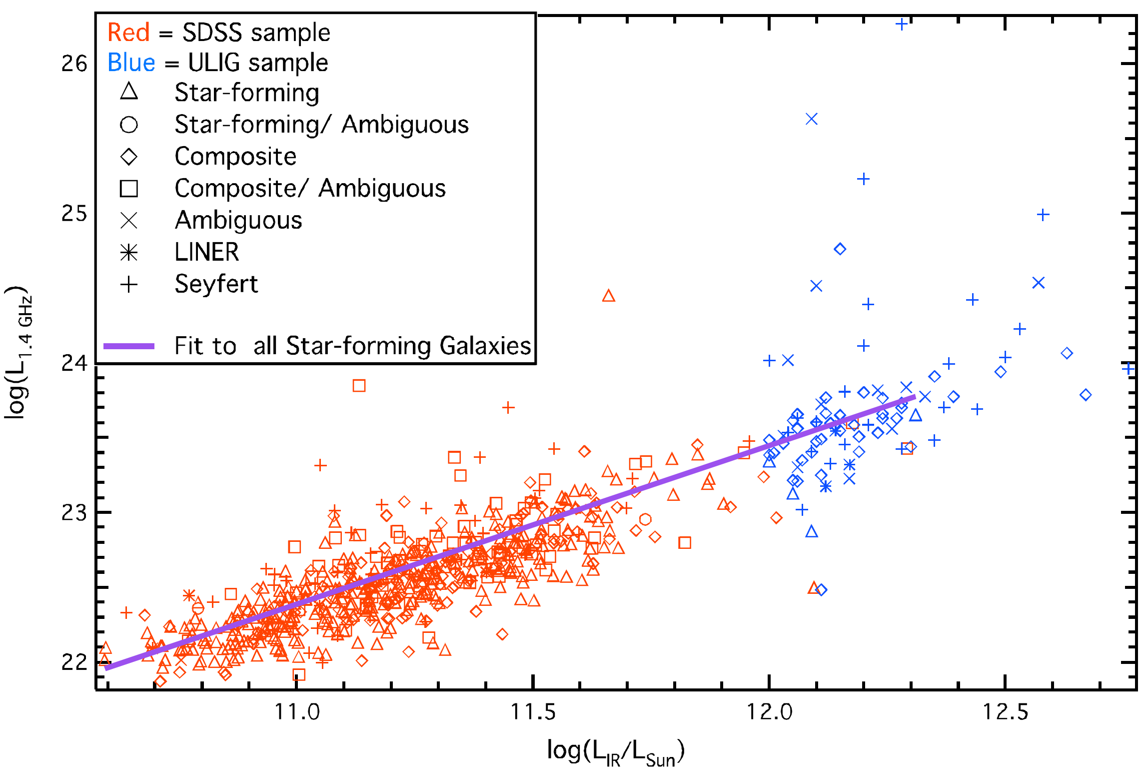
The probability distributions of these pseudo-random data runs were found to be best defined by a modified power law, developed from an energy dissipation theory, producing exponents of $\tau$ = 0.63 ± 0.21 and $\tau$ = 0.51 ± 0.14 for the 1.0 cm and 4.0 cm drop height runs respectively. The effects contributing to the deviating pure power law behavior observed in the pseudo-random bead distribution experiments were qualitatively analyzed in attempt to get insight on the overall behavior of the system in this modified experiment.

SENIOR INDEPENDENT STUDY

## An Optical Study of the Infrared/Radio Correlation of Galaxies

by Kirsten Larson
Advised by Todd McAlpine

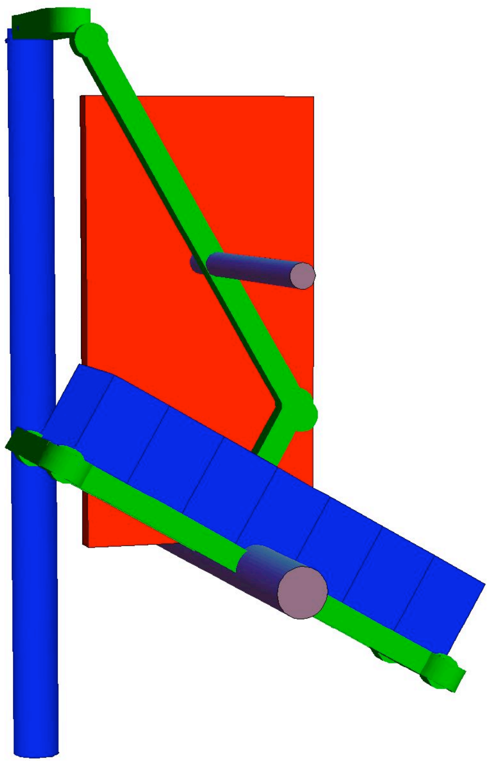
We study the infrared/radio correlation as a function of optical galaxy type to understand the effects of active galactic nuclei on radio emission. Based on previous work, we hypothesized that galaxies with greater AGN activity will have greater radio emission than those without and will therefore lie further off of the infrared/radio correlation. In order to accomplish this, we cross correlate galaxies from data publicly available from the Sloan Digital Sky Survey (SDSS), Infrared Astronomical Satellite sky survey (IRAS), and the National Radio Astronomical Observatory Very Large Array Sky Survey (NVSS). These galaxies are classified by optical spectral type using the method determined by Kewley. We then investigate the infrared/radio correlation of these galaxies using various infrared bands. We find that all galaxies lie in approximately the same area on the infrared/radio diagram regardless of optical spectral type with only a few Seyfert and composite galaxies lying slightly above the correlation. We calculate the linear fit to the star-forming galaxies and obtain a slope of 0.884 ± 0.006 using the 60 μm IR band, which is smaller than the one to one correlation found in the literature. We also calculate the linear fit and obtain a slope of 0.991 ± 0.006 in the far-infrared (combined 60 μm and 100 μm IR bands), which is comparable to the one to one correlation found in literature. When comparing our SDSS selected data to 85 galaxies in the IRAS 1Jy ultraluminous infrared galaxy sample, we find that the RMS deviation from the star-forming linear fit in our SDSS selected sample is smaller than that of the ultraluminous galaxies. We conclude that the strength of radio emission in Seyfert and composite galaxies is not determined solely by the strength of their AGN. It is possible that the observed radio emission from galaxies with AGN is determined by a combination of orientation, black hole mass, and accretion rate, as well as the merger stage of a galaxy. This would explain the larger spread in radio luminosities observed in Seyfert galaxies. However more study is needed to determine this.

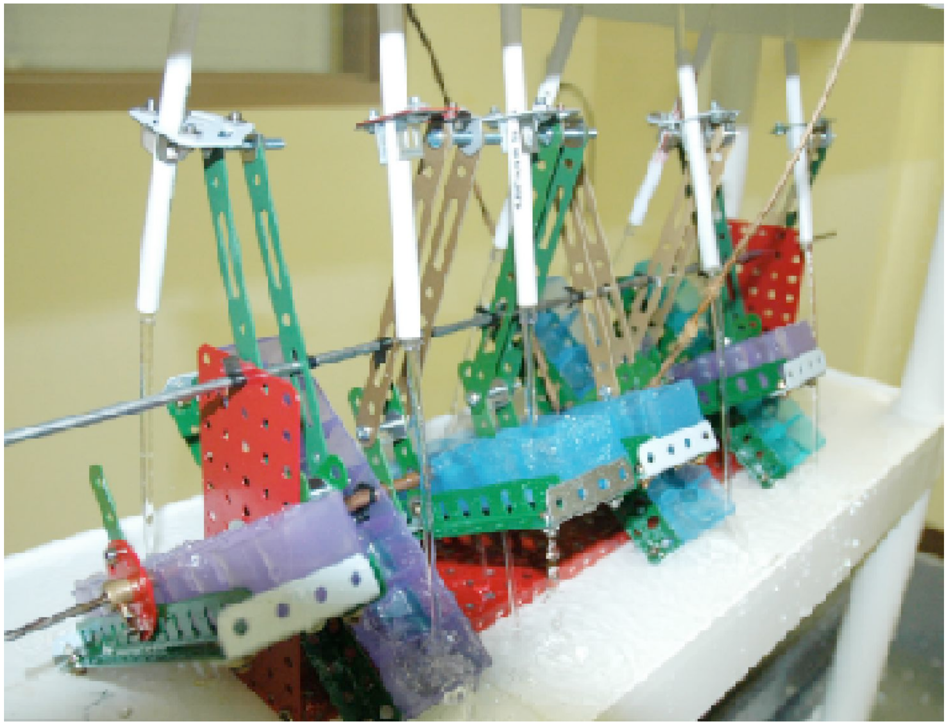


SENIOR INDEPENDENT STUDY

**Experimental Observation of Solitons Propagating in a Hydro-Mechanical Array of One-Way Coupled Oscillators**
by Kelly Patton
Advised by John Lindner

Two-way coupled systems have been studied extensively and are well understood. One-way coupled systems have only been studied in the past five years, mostly through theoretical or computational work. These systems at first glance seem impossible, as they appear to violate both Newton's Third Law and energy conservation. Nonetheless, we have built a mechanical one-way coupled array that is powered by falling water. This array displays the propagation of solitary waves known as solitons, a defining feature of one-way coupled systems. The dynamics of the mechanical array has been analyzed and compares well to the theoretical and computational predictions.

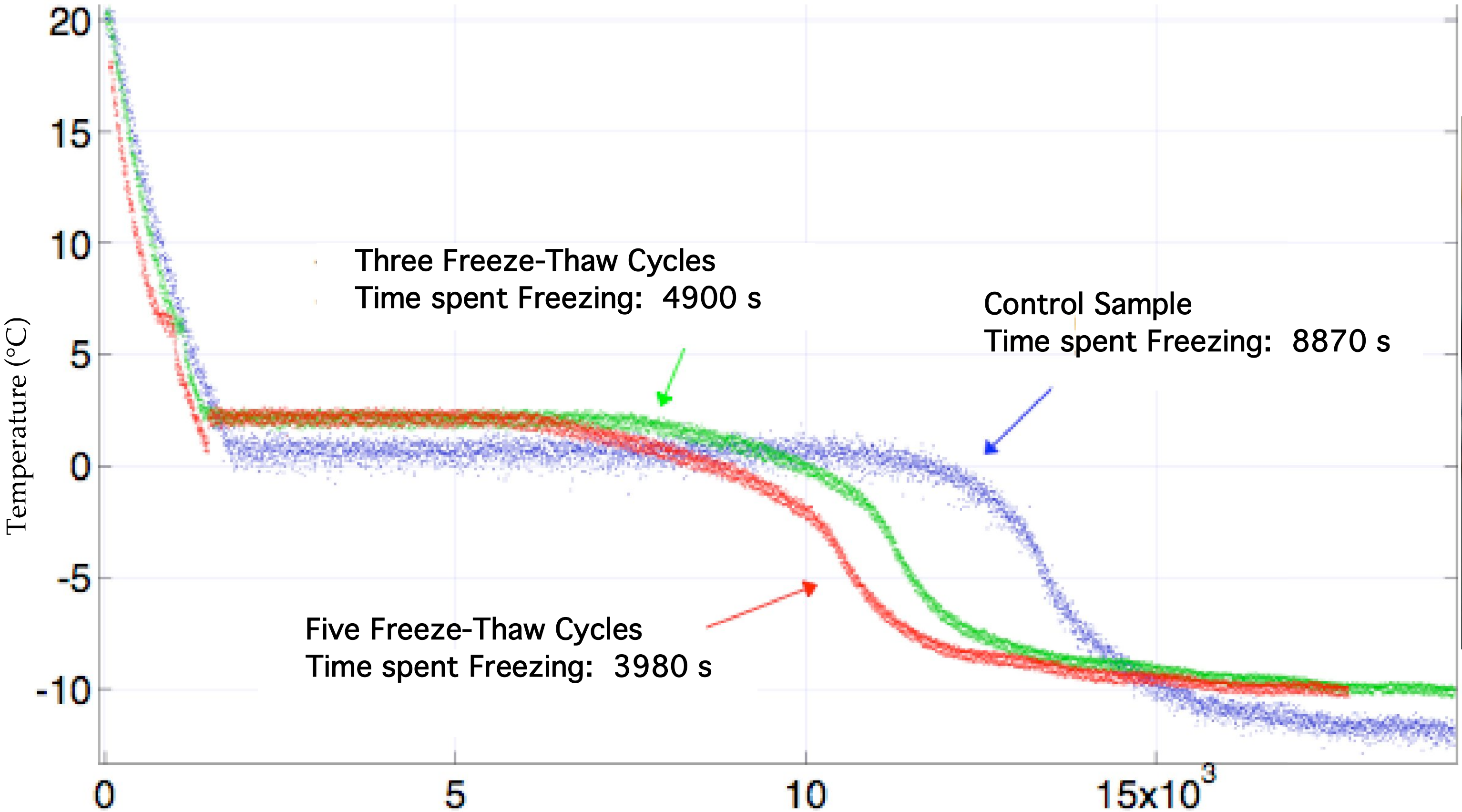


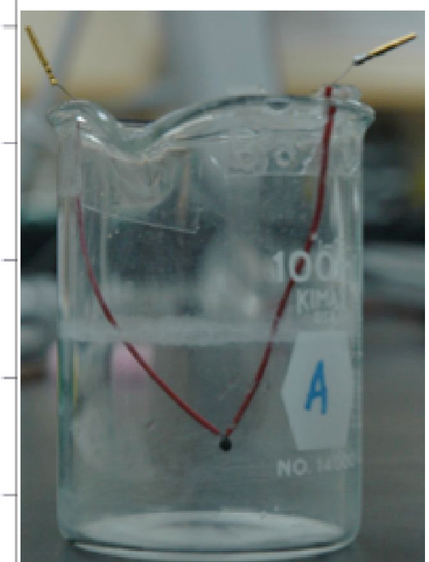


# SENIOR INDEPENDENT STUDY

**When Does Hot Water Freeze Faster than Cold?**
**Investigation of the Reproducibility and Causes of the Mpemba Effect**
by Joseph Thomas
Advised by Susan Lehman

An investigation into the reproducibility and possible causes of the Mpemba effect has been performed. The Mpemba effect is the name given to the common observation by non-scientists that initially hot water appears to freeze faster than initially cold water. Previous scientific studies of this effect have found conflicting results. These discrepancies appear to be due mainly to inconsistent definitions of freezing based on visual observation. We have investigated the Mpemba effect by continuously monitoring the temperature of a sample of water to determine the amount of time needed for the water to turn completely to ice, as indicated by the temperature falling below its freezing temperature. We have successfully observed the effect repeatedly and have found it to be dependent on the history of the sample rather than the sample temperature when placed into the freezer. Water briefly heated to 100 °C then cooled to room temperature froze approximately 50% faster than water which had not been heated. The effect on the freezing time of increasing or decreasing the amount of dissolved gas in the water will also be discussed.

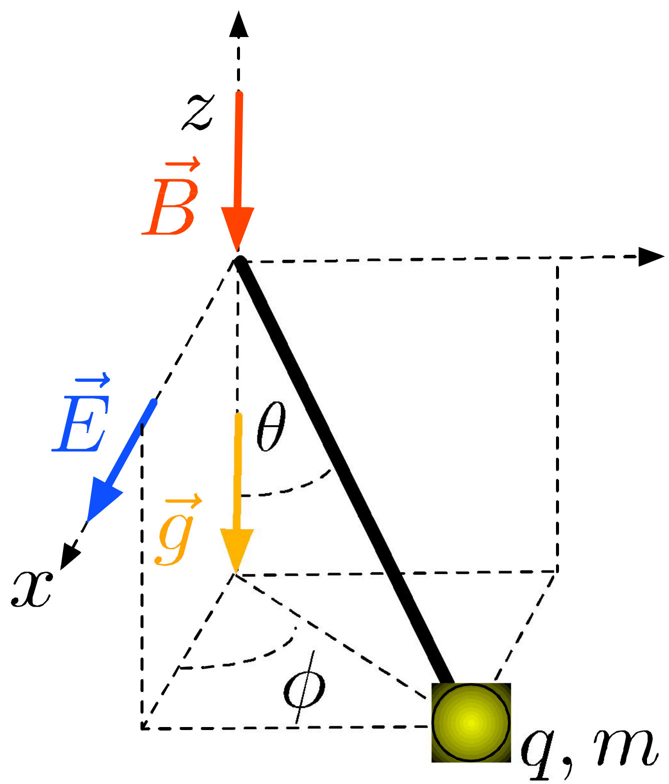


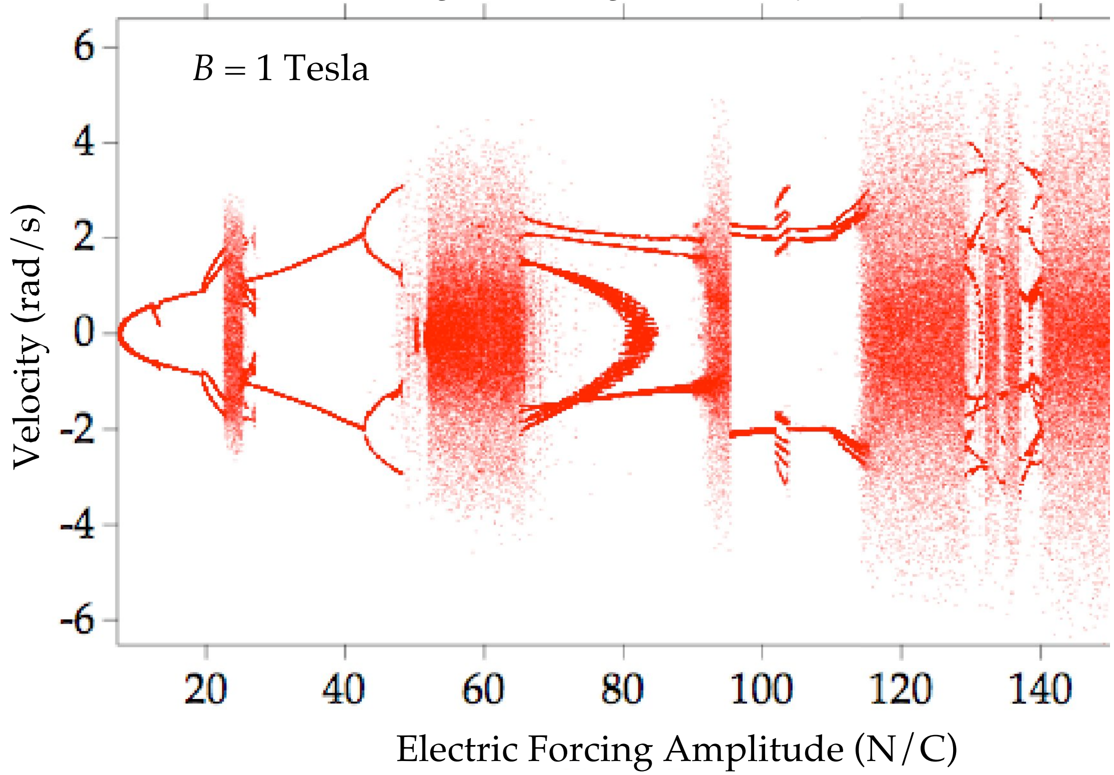
**A Simulation of a Charged Pendulum in Electric and Magnetic Fields**

by Mark Wellons
Advised by Todd McAlpine (Physics)
and Denise Byrnes (Computer Science)

For this independent study we constructed a simulation of a damped, charged, spherical pendulum in time-varying electric and magnetic fields and studied the pendulum's long term behavior. By analyzing a large number of oscillating electric field amplitudes and a number of constant magnetic field strengths, sets of system parameters that force aperiodic behavior in the pendulum were mapped. We find that as the electric field amplitude increases, the pendulum's long term behavior moves through periods of periodicity and aperiodicity. In addition, the qualitative effect of the magnetic field on the pendulum's periodicity is demonstrated. We find that the magnetic field narrows the windows of aperiodicity, and this effect increases as the magnetic strength increases. Each set of system parameters is independent of the others, so computation is parallelized using an Xgrid cluster. Further anaylsis of the pendulum's aperiodic behavior could rigorously show the system to be chaotic.




*Bifurcation diagram when magnetic field is equal to one tesla.*



# AWARDS AND HONORS

The Arthur H. Compton Prize in Physics

·established in 1928 by members of the class of 1913 in honor of Dr. Compton, who received the Nobel Prize in Physics in 1927. Awarded to the senior physics major attaining the highest standing in that subject.

John King Gamble
Kelly Marie Patton

The William H. Wilson Prize in Mathematics

·established in 1926 in memory of William H. Wilson, of the class of 1889, professor of mathematics in the College from 1900 to 1907. The prize is awarded annually to that member of the senior class who has shown the greatest proficiency in mathematics.

John King Gamble

Summa Cum Laude
Kelly Marie Patton
John King Gamble

Cum Laude
Kirsten Lija Larson
Mark Thomas Wellons

Phi Beta Kappa
*John King Gamble
*Kirsten Lija Larson
*Kelly Marie Patton
*election on basis of junior standing

Speaker for the Class of 2008
John King Gamble

The Jonas O. Notestein Prize

·established in 1923, honors Dr. Notestein, who taught Greek and Latin at Wooster from 1873 to 1928. The prize is awarded to the student who has graduated with the highest scholarship for the whole college course.

Kelly Marie Patton

The Mahesh K. Garg Prize in Physics

·awarded annually to an upper-class physics major who has displayed interest in and potential for applying physics beyond the classroom.

John King Gamble

The Edward Taylor Prize

·established in 1876 by A.A.E. Taylor, President from 1873-83. The prizes are awarded to students who have attained the highest and second highest academic standing during their first-year and sophomore years.

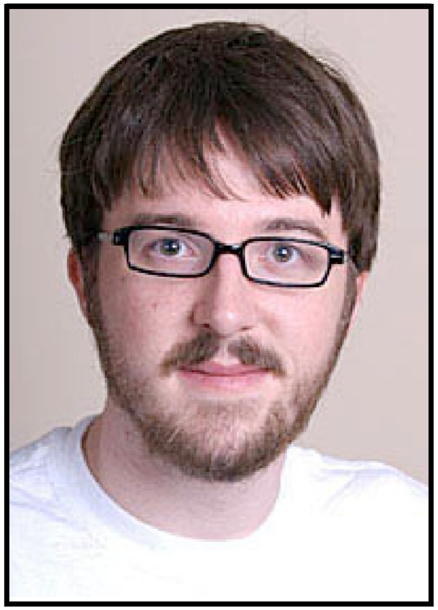
Evan Z. Heidtmann ‘09

The Joseph Albertus Culler Prize

·established in 1942, recognizes excellence in the field of physics. The prize is awarded to the first- or second-year student who has attained the highest rank in general college physics.

Heather Jean Moore ‘10

# AWARDS AND HONORS



*John Gamble '08 has become the fifth Wooster physics major in seven years to win a National Science Foundation Graduate Research Fellowship.*

John Gamble, a senior physics and mathematics double major at The College of Wooster, has been awarded a National Science Foundation (NSF) Graduate Research Fellowship. Gamble, who carries a 3.97 grade point average, plans to use the $120,000 grant to pursue a Ph.D. in physics at the University of Wisconsin, Madison.

"I am very excited about the fellowship," said Gamble, a resident of Erie, Pa. "It will give me an opportunity to focus on classes and research without having to worry about funding."

The National Science Foundation awards graduate fellowships based on the intellectual merit of candidates (competency in conducting scientific research) and the broader impacts of their scientific activities. Applicants are evaluated on their ability to effectively integrate research and education at all levels. NSF awards seek to encourage diversity and broaden opportunities for students in science. In addition, the graduate fellowship program supports students whose research will enhance scientific and technical understanding, and whose projects will benefit society.

Gamble, whose primary interest is theoretical condensed matter physics and quantum computation, was chosen for the fellowship because of his academic record as well as his commitment to the Physics Club's outreach program, which brings physics demonstrations to elementary schools throughout the county.

Gamble credits Wooster for providing him with a number of research opportunities, particularly Wooster's nationally renowned Senior Independent Study (I.S.) program, which matches each student with a faculty mentor in a yearlong research project that culminates in a graduate-level thesis, performance, or exhibition of artwork. He also noted the importance of being able to participate in research programs during each of the past three summers, including one at Wooster.

"John is a superb and multi-talented student who richly deserves his NSF Fellowship," said John Lindner, professor of physics and Gamble's Senior I.S. advisor. "It has been wonderful working with him this year on his senior thesis, which mathematically explores the foundations of quantum mechanics, and on the award-winning Physics Club video 'Theoretical Football,' which he directed and edited."

Shila Garg, dean of faculty and professor of physics at Wooster, spotted something special in Gamble when he worked in her lab at a Research Experience for Undergraduate session after his first year. "I am not at all surprised that John received an NSF Graduate Fellowship," she said. "He is not only an extremely bright student, but he also takes the responsibilities of being a scientist very seriously.

"John is interested in making science exciting and accessible to everyone," added Garg. "This has been obvious from his leadership role in the Physics Club outreach activities in the elementary schools. His excitement for physics is contagious, and his ability to think creatively and work meticulously will serve him well."

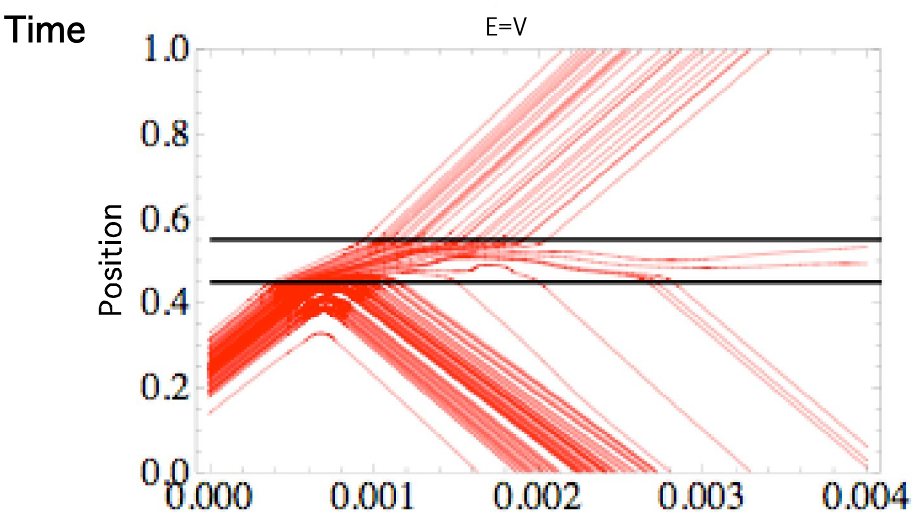
After completing the Ph.D. program at the University of Wisconsin, Gamble will likely follow a path similar to the one taken by his father, John, a 1967 Wooster graduate and now a professor at Penn State University's Behrend campus in Erie. "I'm a hopeless academic," he said. "I love to tackle interesting problems just for the sake of knowledge, and I would really enjoy teaching at the college level."

***—The College of Wooster Office of Public Information***

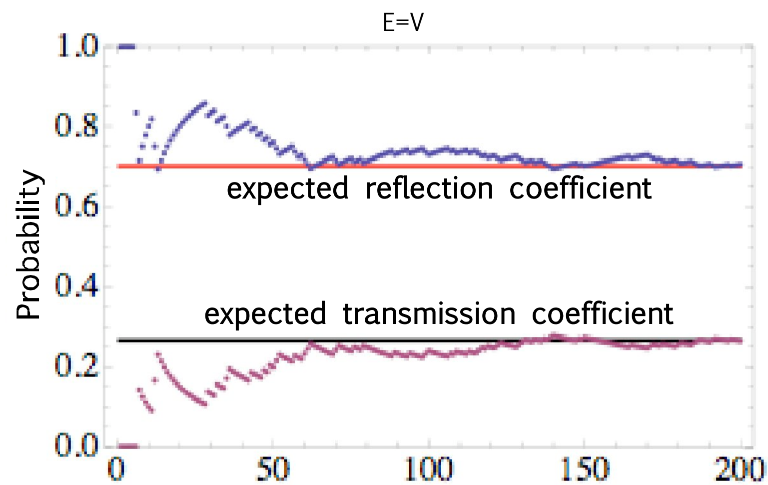
# JUNIOR INDEPENDENT STUDY

**Bohmian Quantum Mechanics and the Finite Square Potential Barrier**
by Matthew Gorski '09

Abstract: This project studies Bohmian quantum mechanics, a hidden variable theory of quantum mechanics that postulates definite particle trajectories. The Bohmian approach is applied to a finite square potential barrier. Using *Mathematica 6,* we compute the particle trajectories in a statistical ensemble for three different energies. It is shown that the probability for a particle to be reflected or transmitted by the barrier approaches the values predicted by the orthodox approach to quantum mechanics. This paper discusses the role of the quantum potential, a concept often associated with Bohmian quantum mechanics. A simulation created in *Mathematica 6* allows a comparison of the orthodox and Bohmian approach to quantum mechanics. The simulation also shows the time evolution of the quantum potential.




*Particle trajectories in a statistical ensemble. 100 initial positions are selected according to the initial probability density. The horizontal lines show the edge of a potential barrier of height V. The energy of the initial wave packet E is equal to the height of the potential barrier V. The times and positions are in generic units.*



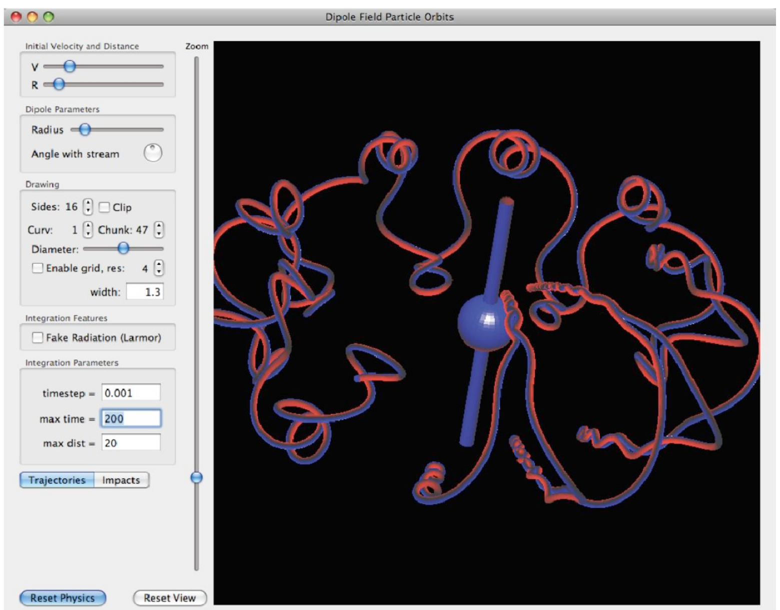

*Transmission and reflection coefficients in the Bohmian (points) and orthodox (lines) approaches. As the number of initial conditions is increased, the Bohmian prediction approaches the orthodox prediction. Shown here is the E = V case.*

# JUNIOR INDEPENDENT STUDY

## Simulating Aurora Borealis: Charged Particles in a Dipole Magnetic Field

by Evan Heidtmann '09

Abstract: The northern lights, aurora borealis, and the southern complement aurora australis have long fascinated polar inhabitants with their colorful displays of shimmering and shifting swaths of light. Explanations for the phenomenon have ranged from angry spirits of the sky to sunlight bouncing around the globe. The current understanding is that the dramatic displays are caused by charged particles from the sun interacting with Earth's atmosphere. Through numerical simulation, we show that the basic behavior observed in the wild can be accounted for by the interaction of a charged particle with an ideal dipole field. We additionally explore some of the orbits that may be found in the vicinity of a magnetic dipole and conclude with recommendations for achieving greater realism.

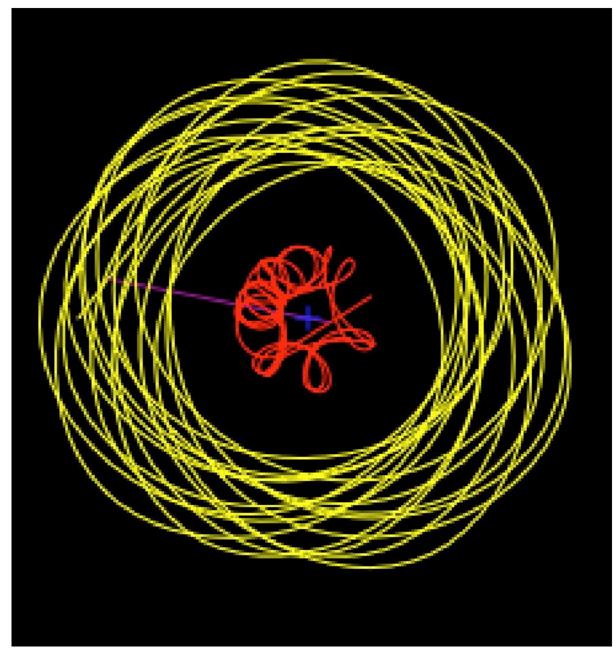



*Given sufficiently small speed or initial radius, particles launched radially can become trapped near the dipole, forever oscillating around the field. In this case, a slightly larger initial speed gives rise to coils approaching both poles. The trajectory begins in the lower left region, pointed away from the viewer, and is terminated at the upper time limit in the final coil near the bottom.*

## Tumbling of Orbiting Barbells

by Frank King '09

Abstract: A computer simulation was written in order to explore the behavior of two extended, rigid bodies in two dimensions. We chose to model the simplest possible bodies that we believed would exhibit the behavior we were interested in: tumbling. We called these orbiters barbells which consisted of two identical point masses connected by a massless rigid rod. While we have been able to qualitatively found regions of interesting behavior the program remains incomplete. There are problems with the text data output and measuring the accuracy of integration. We were also unable to find a set of parameters that show rapid tumbling. Nevertheless, the system has a wealth of interesting behavior to explore with some additional work on the program.



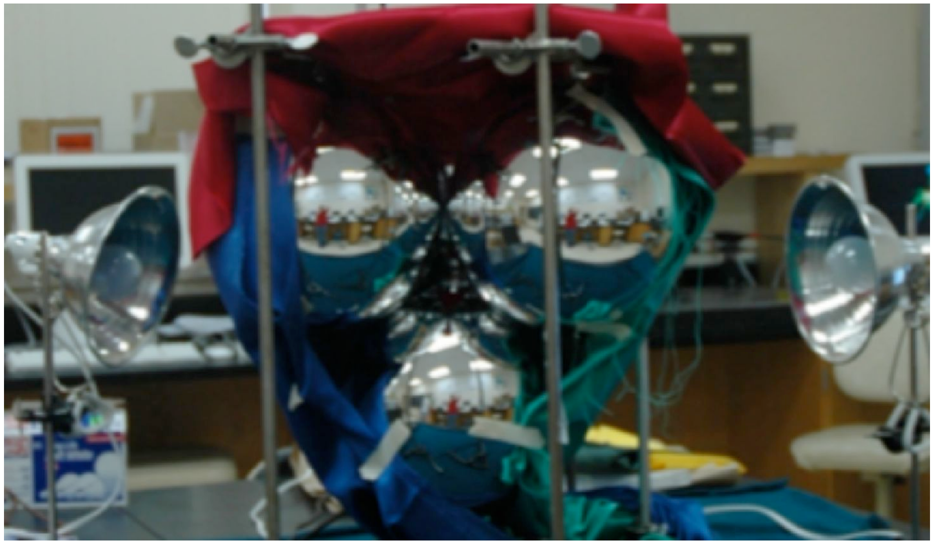
*The orbits of barbells one and two for initial conditions: separation = 1, $m_1$ = 0:1, $l_1$ = 0:4, $\theta_1$ = 0:5, $\omega_1$ = 0:0, $l_2$ = 0:4, $\theta_2$ = 0:0, and $\omega_2$ = 0:0 and a fixed center of mass.*

# JUNIOR INDEPENDENT STUDY

## Analyzing Fractal Dimensions and Self-Similarity in Chaotic Light Scattering

by Mary Elizabeth Mills '09

Abstract: The fractal dimension and self-similarity of portions of an image formed by chaotic light scattering were calculated. Chaotic light scattering was achieved by stacking four mirrored spheres into a pyramid and covering three of the four sides with colored cloth; light was shone through the cloth. The fourth, and open, side was used to look into and take pictures of the image formed by the colored light rays. The image produced a fractal and by looking at the center of the fractal, the dimension was calculated to be 1.32 ± 0.04. The dimension of the three fractals on the sides of the image in the center were calculated to be 1.13 ± 0.06. Self-similarity was determined to be present in the fractal.

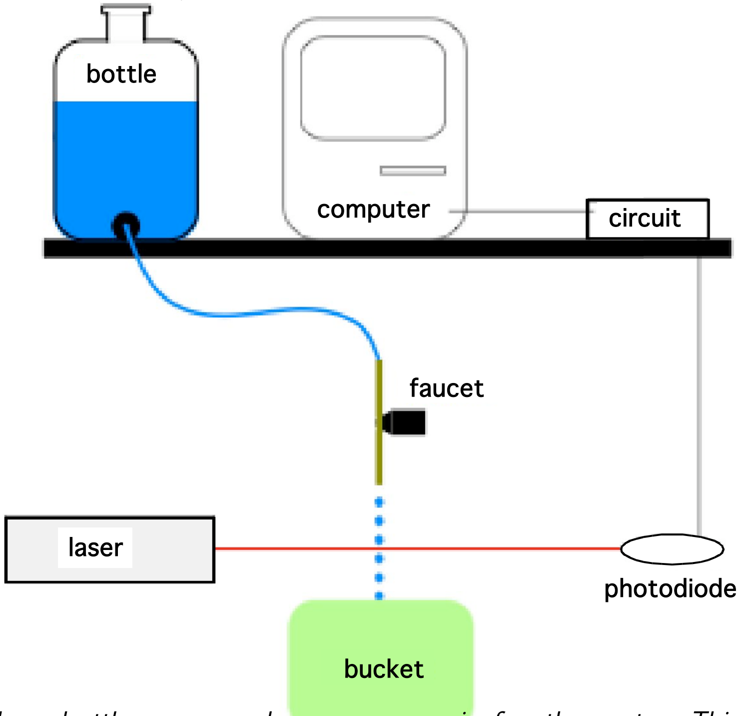


*The setup of the experiment. There were three different color cloths, three different lamps (the third is above the red cloth and outside the picture), and the uncovered side. This side was where all photographs were taken.*

## Drip Drop: A Brief Study of the Dripping Water Faucet

by Martha Roseberry '09

Abstract: An experiment was performed which measured the time between falling drops in the leaky faucet system, and a simulation of a leaky faucet was created by approximating the motion of the drop as a growing mass on a spring. Periodicity and chaos were found for both the simulation and the experiment. However, not enough data were collected to get conclusive results.

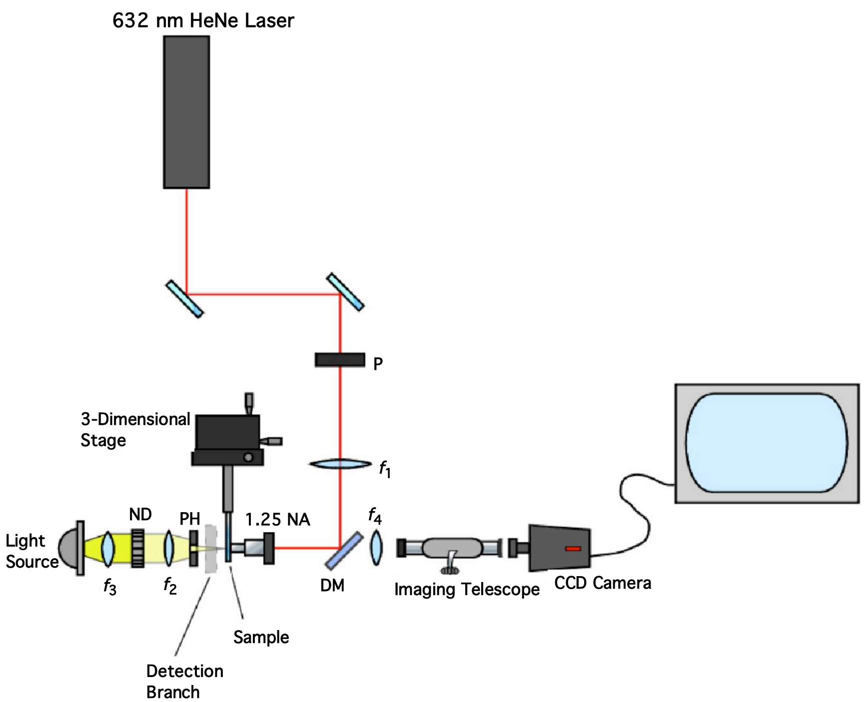



*A glass bottle was used as a reservoir for the water. This bottle was connected to the Nupro faucet, which could be finely adjusted to control the flow rate. The water dripped into a bucket set on the floor. To record the times of the drops, a laser was shone through the path of the drops, and its signal was recorded by a photodiode connected through a circuit to a computer.*

# JUNIOR INDEPENDENT STUDY

## Constructing an Optical Tweezer for the Undergraduate Laboratory
by Henry Timmers '09

Abstract: A setup was constructed to create an optical tweezer that uses a tightly focused laser to trap polystyrene spheres within the focus of its beam. While difficulties in imaging and holding the polystyrene spheres led to an unsuccessful trap, the discovery of a better solution for the spheres will hopefully lead to success in the future. The optical tweezer can be incorporated into an undergraduate lab which would introduce students to biophysics by allowing them to measure physical properties of biological specimens using optical tweezers.




## A Computer Program to Simulate Bird Flocking
by Mike Zappitello '09

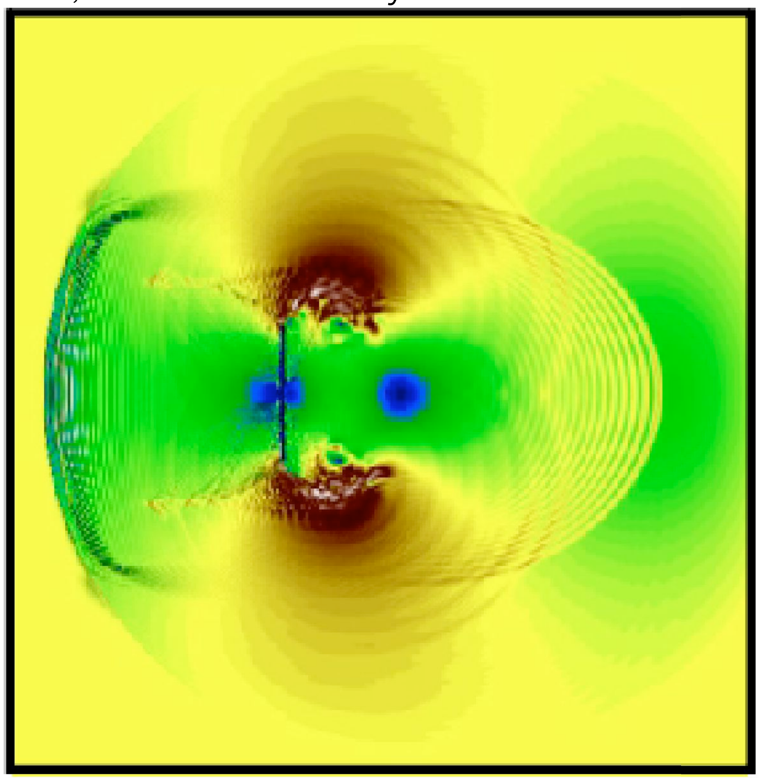
Abstract: A computer program to simulate the natural flocking of birds was created using XCode and Interface Builder. In the model, three different techniques for developing the alignment rules of flock behavior were considered. They are the topological, metric, and random observed methods respectively. In each method the velocity of each individual was computed by averaging the velocities of observed birds. However, each method differed in the technique used to determine the observed birds. Additionally, each method has its own unique parameters. Statistical metrics were written into the program, calculated for a variety of parameters in each flocking method, and then analyzed and plotted in Igor Pro. From these plots, I was able to see that the topological method performed the same under all parameters. Further, the metric method performed similarly, provided the parameter was smalll enough. The random observed method produced a unique pattern as long as its parameter was greater than 1.

# JUNIOR INDEPENDENT STUDY

## Modeling Two Dimensional Incompressible Fluid Flow with the Navier Stokes Equations

by Mark Zimmerman '09

Abstract: The flow of a fluid around a barrier was simulated by numerical integration of the Navier-Stokes equations. The methods utilized include forward time central space finite differencing, a staggered computational grid, and the Euler-Cromer algorithm, which allowed for the observation of well known effects such as reflection, interference, and vortices. More complex and striking features, such as low velocity zones, vortex eyes, and high velocity tails preceding the vortices, were also revealed by the simulation.

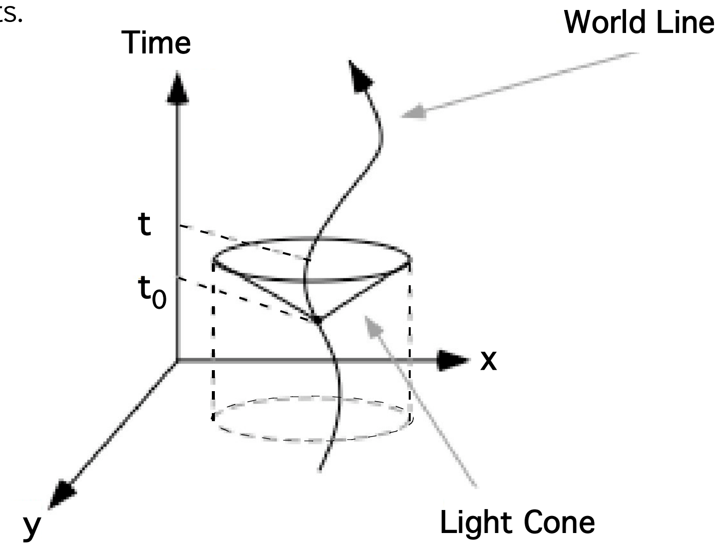


*Picture of a flow with Reynold's number 500. Demonstrates features of vortices, reflected waves, low velocity zones, and vortex eyes.*

## Visually Exploring the Einstein Field Equations

by Averell Gatton '09

Abstract: Visualizations of spacetime curvature are developed in a flexible *Mathematica* notebook. The Einstein field equations are derived in part, and a program is used to show a number of strange stress energy momentum tensors. The experimental metrics include a truncated sinusoidal perturbation and a Gaussian distribution function perturbation to the flat spacetime metric. Visual images developed include simulating the geodesics of light rays, and graphing the stress energy momentum tensor components in matrices of density plots.




*Time evolves upwards. A particle moves along the world line in through 2+1 spacetime. This is seen as a movement in the x-y plane. The light cone shows the distance light can travel in the x-y plane from time $t_0$ to t. The top of the cone has been projected onto the x-y plane with dashed lines.*

# SOCIETY OF PHYSICS STUDENTS

## Events

31 August 2007: Scot Spirit Day
4 September 2007: Colloquium
“Experiments in dynamos: Bringing Earth’s core into the lab”
by Woodrow Shew ‘98, University of Maryland & Nat’l Institutes of Health
12 September 2007: Luce Dinner
26 September 2007: General Meeting
27 September 2007: Colloquium
“A Tethered Polymer Model of Chromatin Organization”
by Joshua Martin ‘02, Brandeis University
2 October 2007: Summer Research Symposium
2 December 2007: Great Lakes Science Center & HRC & Tower City Center
5 December 2007: General Meeting
22 January 2007: Colloquium
“Pushing the Limites of the Standard Model with Lattice QCD”
by Elizabeth Freeland, School of the Art Institute of Chicago
and the Fermilab Lattice Collaboration
23 January 2008: General Meeting
26 January 2008: *Theoretical Physics* Video Shoot
30 January 2008: *Theoretical Physics* Test Screening
27 February 2008: General Meeting
20 April 2008: Taylor Bowl 19

## Physics Club Officers 2007-2008

John Gamble, President
Kelly Patton, Vice President
Henry Timmers, Treasurer
Kirsten Larson, Secretary
John Lindner, Faculty Advisor

## 2007-2008 Outreach School Visits

2 November 2007
Melrose Elementary 3rd Grade
THEME: Force and Motion

16 November 2007
Parkview Elementary 3rd Grade
THEME: Force and Motion

30 November 2007
Lincoln Way Elementary 4th Grade
THEME: Air Pressure

7 December 2007
Melrose Elementary 4th Grade
THEME: Air Pressure

18 January 2008
Wayne Elementary 3rd Grade
THEME: Force and Motion

25 January 2008
Wayne Elementary 4th Grade
THEME: Air Pressure

25 January 2008
Franklin Elementary 5th Grade
THEME: Electricity and Magnetism

8 February 2008
Kean Elementary 3rd Grade
THEME: Force and Motion

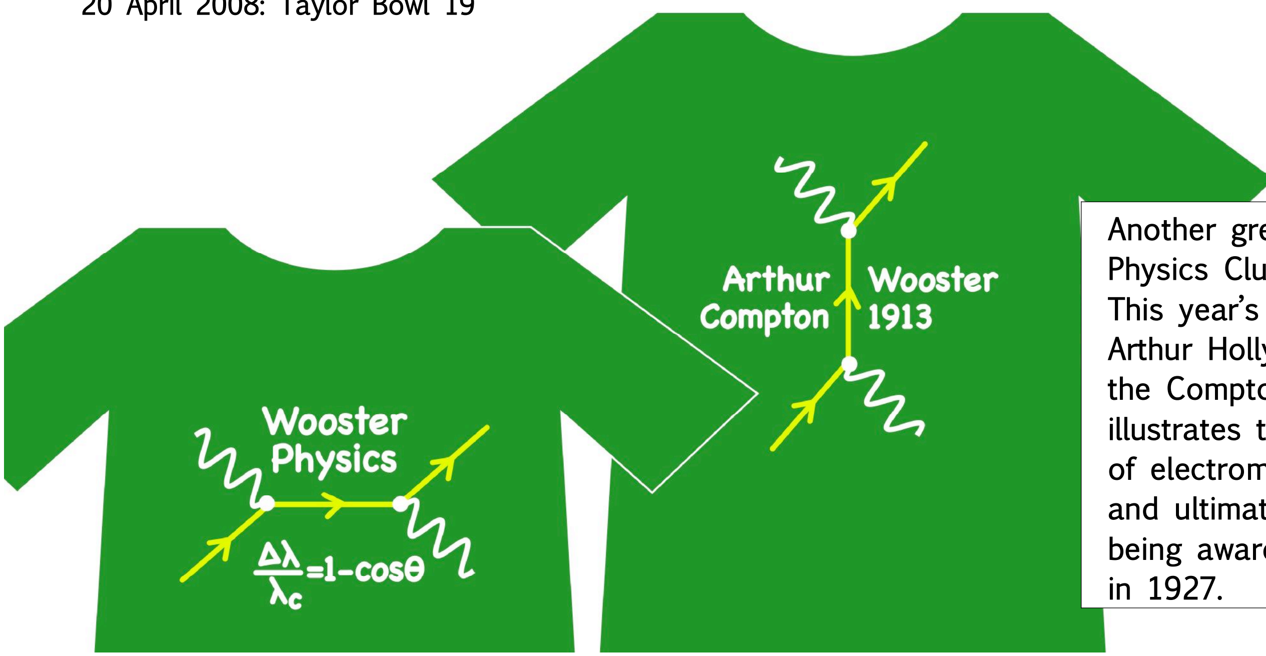
7 March 2008
Smithville Elem 3rd & 4th Grades
THEME: Electricity and Magnetism

4 April 2008
Lincoln Way Elementary 5th Grade
THEME: Electricity and Magnetism

11 April 2008
Apple Creek Elementary 4th Grade
THEME: Air Pressure

25 April 2008
Apple Creek Elementary 4th Grade
THEME: Air Pressure

2 May 2008
Wayne Elementary 5th Grade
THEME: Electricity and Magnetism

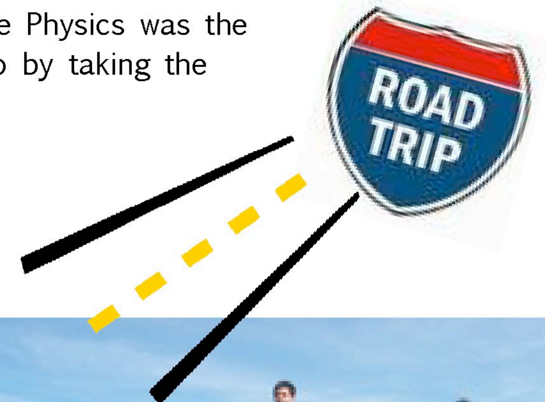


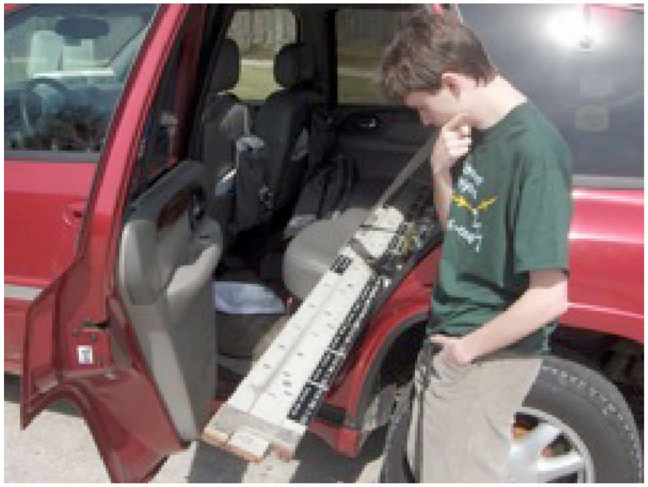

Another great Physics Club T-shirt… This year’s shirt celebrates Arthur Holly Compton ‘13 and the Compton Effect, which illustrates the particle concept of electromagnetic radiation and ultimately led to Compton being awarded the Nobel Prize in 1927.

An entirely new demo set will be added to Physics Outreach this coming year…optics and waves!

# SOCIETY OF PHYSICS STUDENTS

The 2008 Taylor Bowl challenge was the most unique in the history of the event. Since Physics was the losing team last year, they issued the challenge to the Math/CS Department and did so by taking the giant slide rule trophy on a road trip!



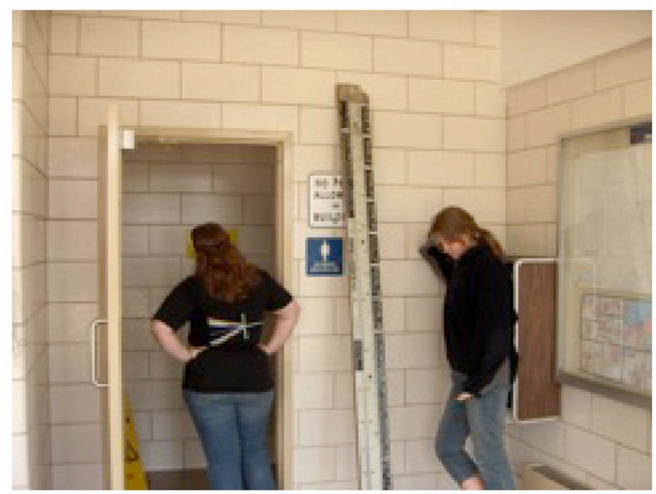
INITIAL DILEMMA


WOOSTER TRACK MEET

THE YACHT CLUB

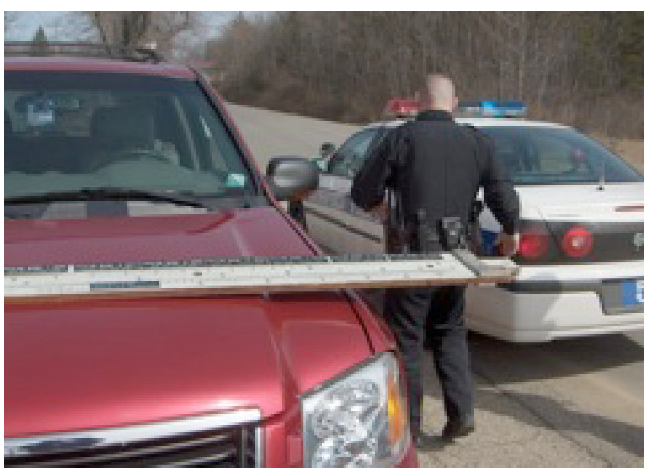

KEEP ON TRUCKIN'


ROLLIN' DOWN THE HIGHWAY



ROADSIDE REST AREA

# SOCIETY OF PHYSICS STUDENTS

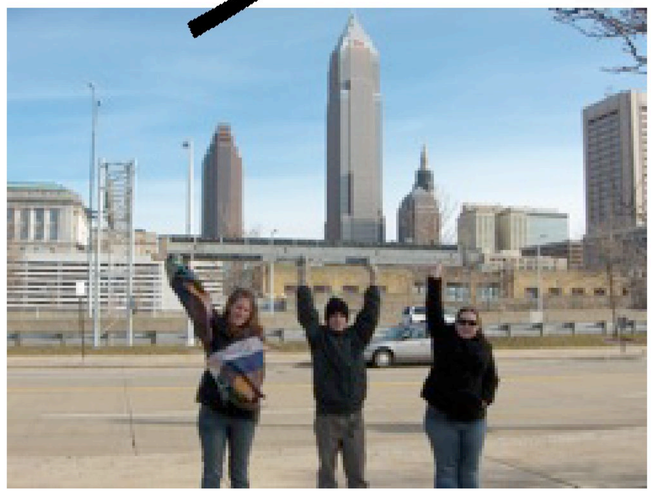
Can you see the headlines?

**"Physics nerds break INTO Mansfield Reformatory"**

(Nobody was actually arrested.)

# SOCIETY OF PHYSICS STUDENTS


GREAT LAKES SCIENCE CENTER



CLEVELAND SKY LINE


1925 STEAMSHIP

TOWER CITY CENTER

Despite a valiant effort and an incredible Taylor Bowl Challenge, Physics lost the giant slide rule trophy once again:
Math/CS 113.2 Physics 107.3


CONCERT and CREOLE at THE HOUSE OF BLUES

# AWARD WINNING VIDEO

The College of Wooster's Physics Club has won the People's Choice Award in the national Nanobowl Video Contest, sponsored by the American Physical Society to coincide with Super Bowl XLII. Unfortunately, they don't have much to show for their efforts. The award, you see (well, actually, you can't), is a nanoscale trophy created in silicon and metal, which is visible only under super high-magnification scanning probe microscopes. The width of the award is about 1,000 times thinner than a strand of human hair.

Get the picture? Well, maybe not.

But that's okay, the students who produced and participated in the award-winning video would be happy to show you what it looks like when magnified 100,000 times in the lab. Not only that, but they would also be interested in illustrating what the game of football looks like from the vantage point of physicists. In fact, that's exactly what they did in their award-winning video.

"Theoretical Football" is a fast-paced three-minute video that illustrates the science behind the game with a heart-pounding, yet humorous, competition between two teams, each consisting of three physics majors. Instead of tackles and touchdowns, however, these students use mathematics and Newton's laws to develop equations that describe what happens when, for example, two players collide at high speed on the field. They also construct the parabolic trajectory of the football as it glides through the air, calculate its range, and derive the formula for a football that is spinning briskly on its axis.

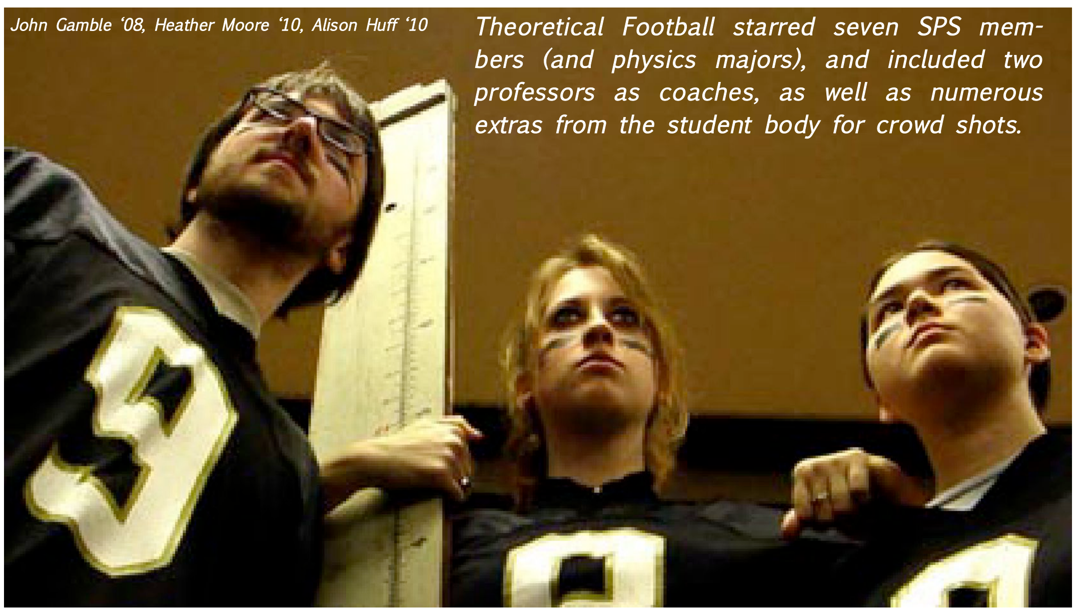
The idea for the video came from John Lindner, professor of physics and advisor to the Physics Club, who thought it would be fun to show what would happen if physicists took up football. "Wooster physics majors are multidimensional," says Lindner. "They have the technical expertise and the creative talent to make a video that is both very clever and very cinematic."

In the video, the team of John Gamble, Heather Moore, and Alison Huff, dressed in black College of Wooster football jerseys, squares off against Henry Timmers, Mark Wellons, and Mark Zimmerman, each wearing a white Wooster jersey. The black team is coached by Lindner, while the white team is led by Todd McAlpine, assistant professor of physics at Wooster. The referee is another physics major, Frank King.

The fans go crazy as their heroes enter the arena, but instead of a gridiron, this battle takes place inside a lecture hall. The tension mounts as the two teams work feverishly in applying the laws of motion to derive the correct formulas describing the game. Even the coaches get caught up in the excitement, as McAlpine chews out one of his players for making a mistake in one of his computations. Lindner, meanwhile, is calmer as he paces the sidelines wearing a hat reminiscent of the one worn by former Ohio State head coach Earle Bruce. In the end, Lindner's team prevails and celebrates by gathering around a giant slide rule.

The video, which was directed and edited by Gamble, was posted on YouTube, where visitors could vote for their favorite entry. Wooster received the most votes in the People's Choice category and took home the trophy, which will have to be enlarged about 100,000 times before it can be displayed.

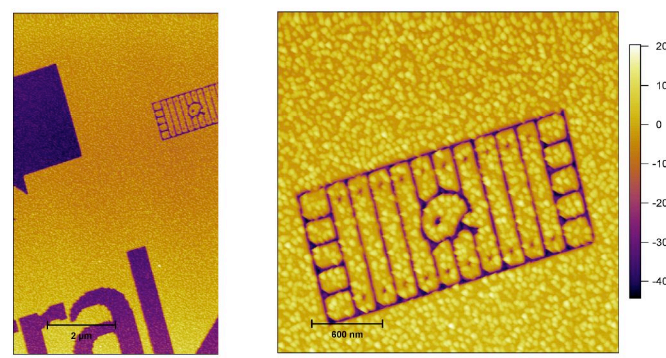
—*College of Wooster Office of Public Information*



*John Gamble '08, Heather Moore '10, Alison Huff '10*

*Theoretical Football starred seven SPS members (and physics majors), and included two professors as coaches, as well as numerous extras from the student body for crowd shots.*

*VIEW THE VIDEO on YouTube: http://www.youtube.com/watch?v=f38ElzpTjg8*




*Richard Sampson (REU Summer 2008 student) used our Scanning Probe Microscope to image our NanoBowl trophy.*

# CONFERENCES

## Midwest Conference for Undergraduate Women in Physics
Univeristy of Michigan
Ann Arbor MI
January 19-20, 2008

In response to the underrepresentation of women in physics, the University of Michigan hosted a two-day conference for undergraduate women in physics that focused on the critical transition from undergraduate to graduate study. The conference's overarching aim was to give young women the confidence, motivation and resources to apply to graduate school and successfully complete a PhD. The conference, which was held concurrently with similar conferences at Yale and USC, was attemded by four Wooster physics majors.  Talks included:  Galactic Eating Habits, The Birth of Neutron Stars and Black Holes, Expanding Opportunities for Women in Physics, Not a Glass Ceiling - What Research Tells Us About Why Women are Underrepresented, Networking - How to Navigate the Labyrinth and Get Your Due, Building a Quantum Computer Atom by Atom, and Simulation-Based Materials Discovery, Design and Innovation, as well as graduate school and career panels.


*Heather Moore, Kelly Patton, Kirsten Larson, Mary Elizabeth Mills*

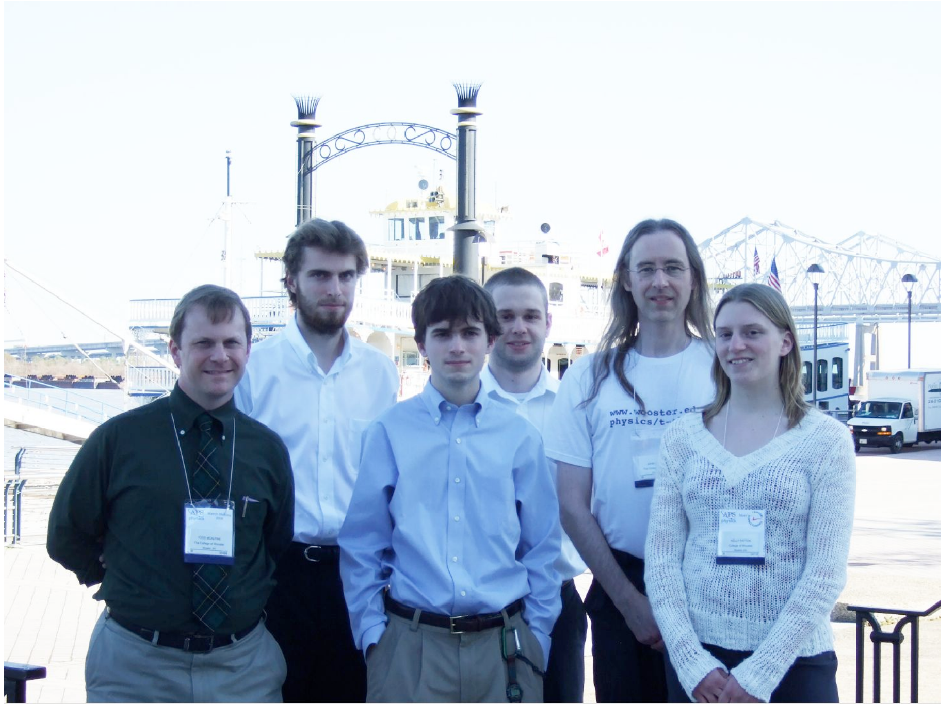
## National Meeting of the American Physical Society
New Orleans LA
March 10-14, 2008

Joseph Thomas* and Susan Y. Lehman
*Does Hot Water Freeze Faster than Cold? Investigation of the Reproducibility and Causes of the Mpemba Effect*

Mark Wellons*, Frank King*†, and Todd McAlpine
*Simulating a charged spherical pendulum in time-varying electric and magnetic fields*

Kelly Patton*, James Gallagher†, and John F. Lindner
*Experimental Observation of Solitons Propagating in a Hydro-Mechanical Array of One-Way Coupled Oscillators*

* Wooster student
† NSF-REU student



*Todd McAlpine, Mark Wellons, Frank King, Joseph Thomas, John Lindner, Kelly Patton*

# SUMMER RESEARCH

A Charged Pendulum in an Electric Field
by Alison Huff, CoW '10 (NSF-REU)

Perturbing Spacetime
by Thomas Linz, Kenyon '09 (NSF-REU)

Order and Chaos in the 2.5-Body Problem
by Jacob Lynn, New York University '09 (NSF-REU)

Experimental Observation of Soliton Annihilation
in a Hydro-Mechanical Array of One-Way Coupled Oscillators
Pat Odenthal, University of Portland '09 (NSF-REU)

Our Cells, Your Cells, and Micelles: 17R4 in Water
by Kelly Patton, CoW '08

Off-Campus Summer Research

Robby Daniels '10 was an intern at Kent Display Systems in Kent OH where he made and tested liquid crystal displays.

Mary Mills '09 spent her summer at the American Institute of Physics creating the new SPS Outreach Catalyst Kit and the website "The Nucleus".

Henry Timmers '09 worked at the Molecular Physics laboratory of SRI International in Menlo Park, CA. He investigated the vibrational relaxation of OH (v=2) using a two laser set up to photo-discossiateozone and create a product of vibrationally excited OH radicals which were probed using the second laser beam to determine the temporal evolution of the radical.

Frank King '09 went to Bucknell University where he researched the quantum mechanics of two-photon interference.

Roger Klein '11 (Physics & BioChemistry Molecular Biology) worked in CoW Department of Chemistry with small heat shock proteins ("sHsps").

Electrical Characterization of Quantum Dots Using Ballistic Electron Emission Microscopy
by Richard Sampson, Columbia '10 (NSF-REU)

It's getting hot in here—or is it? An Investigation into Mpemba Effect
by Ingrid Thvedt, CoW '11 (NSF-REU)

Self-Organized Criticality: Bead Pile Dynamics Across Bead Types
by Mike Winters, CoW '10 (NSF-REU)

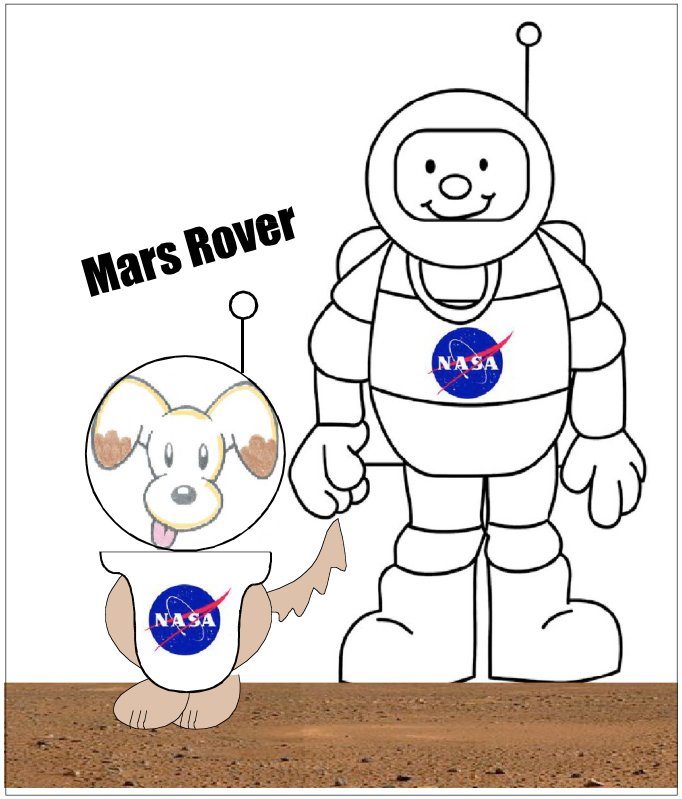
Percolating Electrons Through Steel Shot and Glass Beads
by Mark Zimmerman, CoW '09 (NSF-REU)

Bryna Clover, a graduate student from University of Maryland at College Park, worked with Don Jacobs on heat capacity in block co-polymer solutions.

John Gamble '08 spent several weeks co-authoring a paper with Dr. Lindner on his Senior I.S. research on quantum decoherence.


*Front: Ingrid Thvedt, Bryna Clover, Kelly Patton, Alison Huff, Mike Winters, Mark Zimmerman, Pat Odenthal, Susan Lehman*
*Back: Todd McAlpine, John Gamble, John Lindner, Jacob Lynn, Richard Sampson, Thomas Linz, Donald Jacobs*

# PHUN DOG PHYSICS



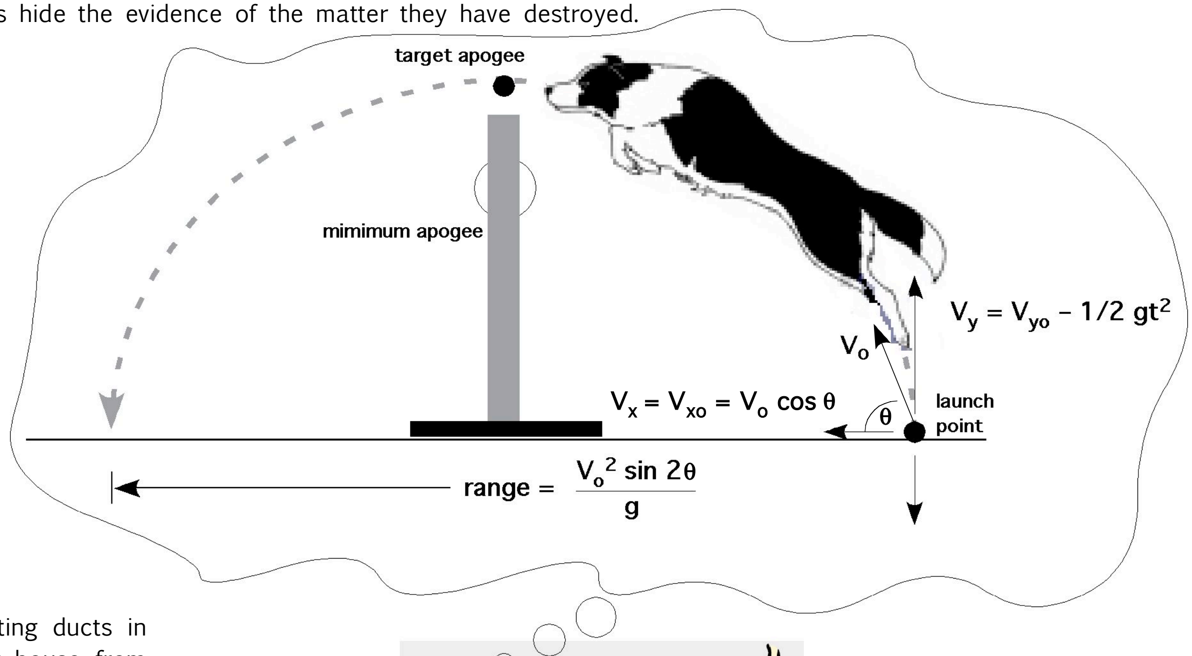

## Canine Physics Glossary

Dog Laws of Motion: 1. For every living thing that moves in a dog's territory, other than immediate family and pack, there will be a proportionate bark and chase reaction.
2. Dogs at rest tend to stay at rest, unless something interesting occurs to arouse them, then the first Law of Motion will occur.

Dog Laws of Conservation: 1. A closed mouth will not gain or lose anything - a dog will open mouth to receive biscuits and close mouth to refuse medication. 2. A dog at rest, with closed eyes, will not lose any energy.

Quantum Leap: How high a dog can jump up when he greets you; height being proportional to level of dog's enthusiasm and quality of the clothes you are wearing. (Dry clean only clothes result in maximum height.)

Black Hole: 1. The cavities in your flower bed that are a direct result of your dog's boredom. 2. Where dogs hide the evidence of the matter they have destroyed.




Dog Laws of Gravity: Balls and treats thrown into the air are easier to catch on the way down. Food going down tastes better then when coming back up, but a dog will eat it either way.

Defiance of the Law of Gravity: If it is undigestible, what goes down, must come up.

Dog Laws of Thermodynamics: 1. Dogs will cover your heating ducts in winter and air conditioning vents in summer, preventing your house from being properly heated or cooled. 2. When you are hot, your dog will want to sleep with you; if you are cold and want your dog to sleep with you, he will choose to sleep on the floor.

Cosmological Constant: You are the center of your dog's universe. In his eyes, the sun rises and sets in your smile towards him. Be kind to him, take good care of him, and love him every day of his life.

-adapted from Physics for Dogs by Lexiann Grant

What they are <u>really</u> thinking

# ALUMNI NEWS

On August 22, Jeremy Hohertz '06 received his Master of Science in Physics from Miami Universit.y. He has begun a Ph.D. program at Wake Forest University.

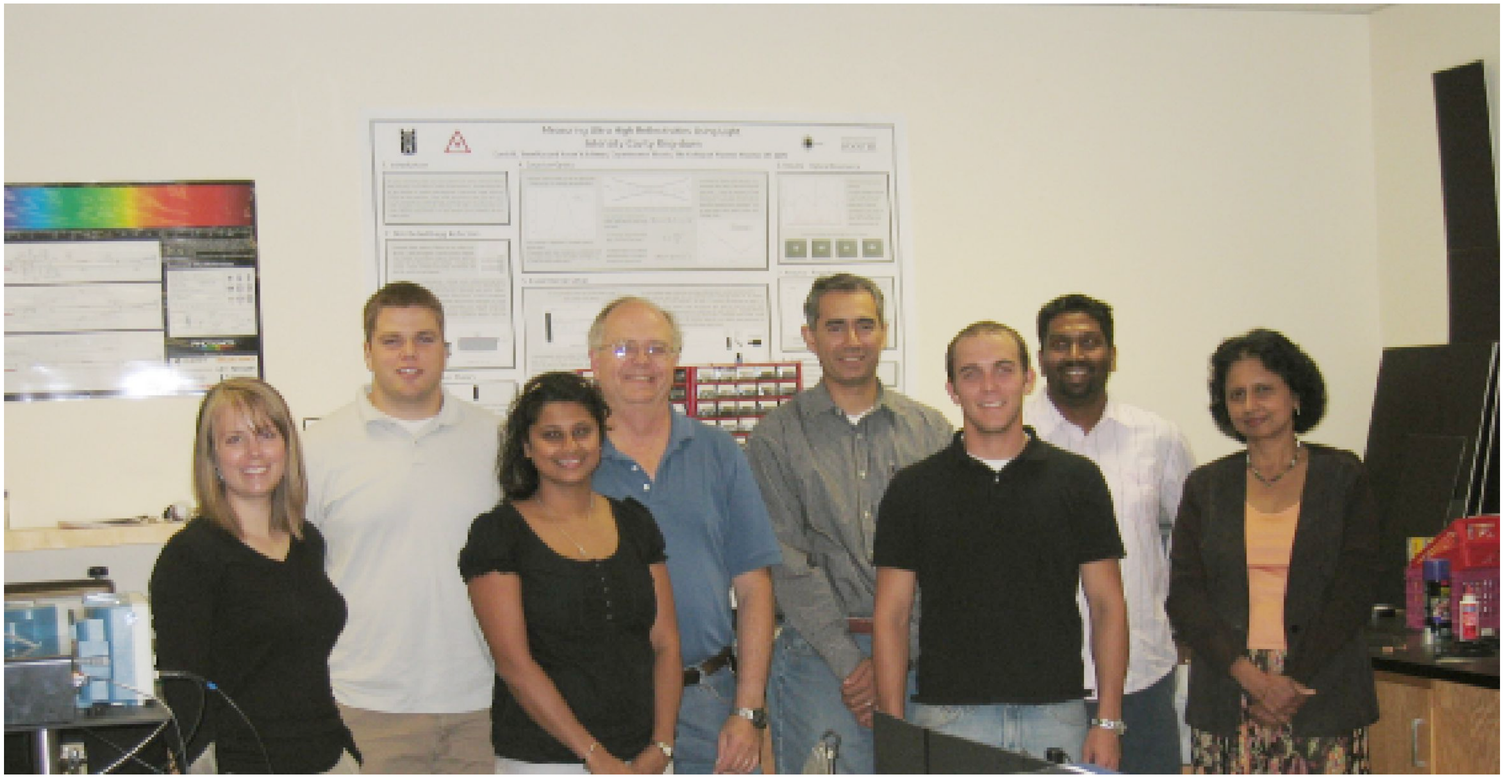
David Miller '02 recently completed his Ph.D. in Physics (Computational Systems Biology) from Drexel University.

Ryan Hartschuh '03 received his Ph.D. from the University of Akron last December and is now a program manager at NineSIgma Inc. Ryan and his wife Betsy Bare Hartschuch '01 welcomed baby daughter Audrey Rylee on July 29th.

Paul Hall '95 went on to get his Ph.D. at the University of Rhode Island's Graduate School of Oceanography, where his research focused on modeling convective flow in the Earth's mantle using a combination of computational and laboratory methods. He is now an assistant professor position in the Earth Sciences Department at Boston University and is hoping to attract graduate students with physics/math backgrounds to the field of geodynamics.

Excavation at Wooster's soccer field recently resulted in the unearthing of two time capsules. The capsules were apparently buried by Scott Reed Gunselman '87, and the contents were turned over to the Office of Alumni Relations. Look for more information on the contents in an upcoming College of Wooster publication.

Several Wooster physics alums will be featured in an upcoming issue of *Wooster* alumni magazine. All five of them now work for Kent Displays Inc. in Kent, OH. Kent Displays is the world leader in the research, development, and manufacture of Reflex™ Liquid Crystal Display products.



*Erica Bramley Montbach '97, Mark Lightfoot '05, Nithya Venkataraman '04, Don Jacobs, Asad Khan '93, Robby Daniels '10 (summer intern), Clinton Braganza '03, and Shila Garg*

# ALUMNI NEWS

Derek Somogy '02 joined the law firm of Renner Kenner in Akron, OH, after graduating from the Moritz College of Law at The Ohio State University. Derek works in all areas of intellectual property, including litigation.

Sean English '00 is doing a surgical residency at University of Michigan Health System after receiving his M.D. degree from University of Pennsylvania.

Amy Christine Rauch McDaniel '99 received the "Teacher of Promise" award from the College of Education and Human Development at George Mason University.

*Brad Lignoski '03 walks a highline across the Monkey Face formation at Smith Rock State Park in central Oregon.*

Andy Kuck '99 is a Senior Software Engineer at Overwatch Textron Systems in Austin, Texas.

Give us a shout!

www.wooster.edu/physics/alumni

Click on
Alumni Update Form

or email:
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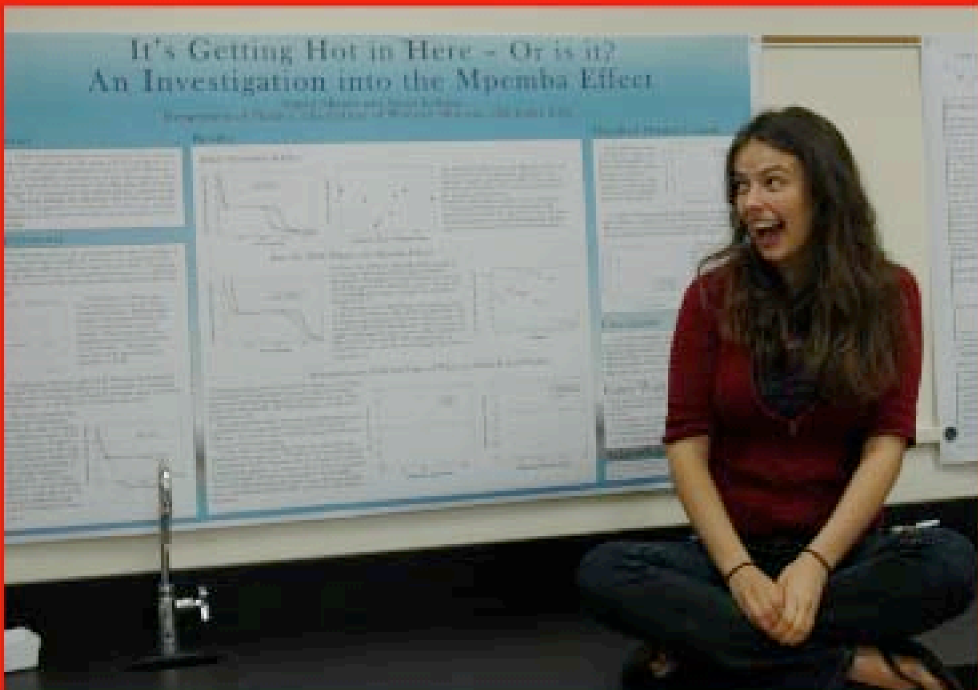
JMiddleton@Wooster.edu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