

## **"Nanoscience in the 21st Century"**

### **Fall Meeting of the Illinois Section of the AAPT**

*October 15-16, 2004*

**Physics Department, Bradley University, Peoria, Illinois**

*Friday, October 15, 2004*

**9:30 - 12:00 Registration - Main Lobby, First Floor Entry, Olin Hall**

**10:00 - 12:00 Workshop 2. "Loop 'em and Launch 'em with CPO Science Physics"**  
Darin Christianson, CPO Science. Olin 45

**Workshop 3. "Simple Experiments in Physics"**  
Thomas Kuhn, Pasco Scientific. Olin 37

**12:00 - 1:00 Lunch on your own**

**1:00 - 4:00 Registration - Main Lobby, First Floor Entry, Olin Hall**

**1:00 - 1:15 Welcome - Dr. James H. Craig, Jr., Chairman, Bradley Physics, Olin 168**

**1:15 - 3:30 Session A - Contributed Papers - Olin 168**

Session Chair: Douglas Early, Bradley University

**1:15 - 1:35 - A1**

**Introducing the Augustana Planetary Science Exam (APSE).** *Lee Carkner*, Augustana College, Rock Island, IL 61201. The Augustana Planetary Science Exam (APSE) is a 34-question, multiple-choice test designed to assess the backgrounds and basic planetary science knowledge of undergraduates taking a "general education" type solar system course. Some results of the first trial run of the APSE at Augustana College will be presented. We will examine what students know about the planets before entering the class, both in terms of strengths and misconceptions, as well as look at variations in student backgrounds. We will also compare students' math performance in class with different indicators of pre-class math preparedness.

**1:35 - 1:55 - A2**

**Computational Physics B.S. Degree: 5 Year Review.** *Richard Martin and Q. Charles Su*, Illinois State University, Normal, IL 61790-4560. Five years ago, in an attempt to offer majors more flexible degree options, the Illinois State University Physics Department initiated an undergraduate B.S. sequence in computational physics. The sequence parallels the traditional physics major for the first three semesters then diverges with specialized courses designed specifically for computational physics majors, as well as computationally focused elective courses and research experiences. We will present data on the demographics of the students who have completed the major, and the results of an assessment based on alumni questionnaires and current physics major focus groups.

**1:55 - 2:15 - A3**

**The Use of a Heat-Treated 14% Chromium Stainless Steel to Produce Large-Scale and Small-Scale Torque Sensors.** *Christopher C. Jurs, Jacob R. Hoberg, Jason T. Orris, Doug A. Franklin, and Mark S. Boley*, Western Illinois University, Macomb, IL 61455. We have produced a large scale (0.75 inch) and a small scale (0.25 inch) torque sensor from type ESR-420 stainless steel for industrial torque transfer or small scale medical applications by appropriately polarizing two adjacent sections of the shafts with oppositely directed circumferential magnetization. The resultant field signal, found to be linear with applied torque up to 15 N-m, emanated from the domain wall formed between the two regions and was easily detected with a Gaussmeter. A two-step heat treatment, consisting of a rapid quench to room temperature from 1038°C, followed by a slow 3-day cool from 871°C to restore desired magnetic and mechanical properties, was applied to the samples to enhance performance. The torque-load sensitivity (field signal in microgauss per unit applied shear stress in pounds per square inch or psi) was found to be remarkably linear and as high as 237 microgauss/psi, with

excellent re-zeroing capability, making it an ideal candidate for the small-scale applications where weak signals are usually a plaguing problem. Simultaneously, the magnetic hysteresis properties of the samples were studied prior and subsequent to the heat treatments. The axial coercive force was found to remain consistently low around 5-6 Oe throughout heat treatment, in correspondence with the large sensitivity values, while the circumferential coercive force remained around 25-27 Oe, which is sufficient to guarantee integrity of the magnetically polarized regions comprising the sensor at both scale levels.

**2:15 - 2:35 - A4**

**Design and Construction of an Electron-Beam Evaporator for Molecular Beam Epitaxy.** *Dan Silvius, Chris Foster, Peter Petrany, Mike Gahl, Kelly Roos*, Bradley University, Peoria, IL 61625. We have designed and built an evaporator for the deposition of single metallic atoms on surfaces in Ultra High Vacuum ( $< 10^{-10}$  Torr). The Molybdenum evaporator crucible is heated by electron bombardment via acceleration of thermionically emitted electrons from a Tungsten filament. We will describe the design and construction of the evaporator and report on its functional stability.

**2:35 - 2:55 - A5**

**Fermionic Quantum Cellular Automaton.** *Erick Blomberg, Kelly Roos*, Bradley University, Peoria, IL 61625. The quantum cellular automaton (QCA) is a complex dynamical system that we use to model the motion and interactions of virtual fermions. The time evolution of the QCA is derived from the predictions of the Dirac equation and the Pauli Exclusion Principle. The QCA does an excellent job of illustrating the intriguing nature of quantum mechanics of non-interacting fermions in relatively low energy states. In our recent research we have attempted to explain single electron slit diffraction through the interactions of virtual electrons and to create a clearer understanding of the wave-particle duality of fermions and other quantum objects. We will present the basic behavior of the QCA and also the results of our on going work with modeling single and double slit diffraction.

**2:55 - 3:15 - A6**

**Mathematical simulations of ion transport in a Linear and T-shaped Paul trap.** *Jacob Burress and James Rabchuk*, Western Illinois University, Macomb, IL 61455. Ion traps present a possible pathway for developing a quantum computer. In ultra-high vacuum conditions, ions can be cooled and stored in linear Paul traps for hours or even days at a time without losing their qubit state. Several recent proposed entanglement schemes for ions do not require the ions to be in specific motional states, removing the need for precise temperature control of the ions in the traps. Quantum computers relying on such schemes need to be modular, and require some or all of the ions involved in large-scale computations to be transported from trapping region to region. In particular, ions would need to be transported around corners, due to the limited size of computer boards. The challenge is to move these ions deterministically without introducing any unknown phase shifts in their internal, qubit states. The transfer rate of ions in a standard linear trap is limited by the allowed switching speeds of the electrode potentials. Allowing for this restriction, we have developed a classical model that allows us to predict the ion motion for a given sequence of electrode potentials that results in deterministic transport of an ion from one trapping region to another. We have preliminarily extended this model to examine ion transport in a T-shaped trap array, in advance of experimental attempts to carry out such shuttling at the Trapped Ion Quantum Computing laboratory at the University of Michigan.

**3:15 - 3:30 - Take Fives**

1. *Roger Malcolm*, "Teaching Physics to Kiwanis and Rotary Clubs"
2. *Ken Mellendorf*, "Peer Review for Homework"

**3:30 - 3:50 Break and Vendors - Olin 45**

**3:50 - 5:15 Session B - Contributed Papers - Olin 168**

Session Chair: Paul Wang, Bradley University

**3:50 - 4:10 - B1**

**Using Molecular Templating to Build Nanometer-Scale SQUIDS.** *Ryan T. Gordon, Alexey Bezryadin, Doug*

A. Franklin, and Mark S. Boley, Western Illinois University, Macomb, IL 61455. We have successfully shown that nanometer scale superconducting quantum interference detectors (SQUIDS) can be constructed using a suspended molecular template technique along with a method of electron beam deposition (EBD) of carbon using a scanning electron microscope (SEM). A rectangular chip, which had a top layer of silicon nitride and a 100 nm trench running down its center, was etched in hydrofluoric acid to ensure the middle layer of silicon oxide was underetched away from the bottom of the trench. Solutions both of regular and fluorinated single-walled carbon nanotubes were deposited on the surface of the chip, and nanotubes were found to exhibit bridge-like behavior by crossing the trench in an irregular and often random pattern. Ambient or local carbon from the imperfect vacuum chamber of the SEM was then used to grow triangular loops on these carbon nanotube bridges by using the EBD technique. If necessary, reactive ion etching was used to decrease the widths of the carbon structures themselves. A thin film of Molybdenum-Germanium (MoGe) superconducting alloy was then sputtered onto the entire surface of the silicon chip. Photolithography was used to create an electrode pattern from the film of MoGe on the surface of the chip. Gold wires were then ready to be attached to the electrodes so that current and voltage across the electrodes could be measured within a liquid helium environment. This particular SQUID geometry created allows for the quantized magnetic flux through the enclosed loop area to be accurately measured, as well as allowing the opportunity to study the magnetoresistance properties.

**4:10 - 4:30 - B2**

**Magnetic Trapping & Levitation.** *Eric Peterson*, Highland Community College, Freeport, IL; *Igor Lyuksyutov and Donald Naugle*, Texas A&M University, College Station, TX. Enhancement of interest in magnetism, through relatively simple levitation demonstrations, comprised the primary motivation behind a NSF sponsored summer program at Texas A&M. Emphasis was placed upon the creation of items that could be made with portability, cost and ease of setup in mind. Novel examples from short web based videos and the presentation of a physical model of magnetic levitation will be shown.

**4:30 - 4:50 - B3**

**Adsorption Studies of Triethylsilane on the Si(100) Surface at 100K.** *P. Petrány, Jose Lozano, James Craig*, Bradley University, Peoria, IL 61606. The adsorption of triethylsilane at 100 K on the Si(100) surface has been studied using temperature programmed desorption (TPD) and time-of-flight electron stimulated desorption (TOFESD). The effect of electron irradiation on the adsorbed layer will be discussed. Evidence for a beta-hydride elimination process accompanying ethyl group desorption will be presented. Results of the effect of electron irradiation of the adsorbed layer on TPD and TOFESD spectra will be presented and discussed.

**4:50 - 5:10 - B4**

**Magnetoelastic Response and Domain Wall Behavior of Two 5% Chromium Heat-Treated Tool Steel Torque Transducers.** *Jacob R. Hoberg, Christopher C. Jurs, Jason T. Orris, Gregory M. Sollenberger, and Mark S. Boley*, Western Illinois University, Macomb, IL 61455. We have produced torque sensors from type A-2 and type H-13 tool steels for industrial torque transfer applications in a 0.75 inch outer diameter hollow shaft by magnetically polarizing two adjacent sections of the shaft with oppositely directed circumferential magnetization. The resultant field signal, found to be linear with applied torque up to 15 N-m, emanated from the domain wall formed between the two regions and was easily detected with a Gaussmeter. A two-step heat treatment, consisting of a rapid quench from a temperature higher than the Curie temperature of the ferromagnetic steel in order to erase magnetic history, followed by a slow cool from a lower temperature to restore desired magnetic and mechanical properties, was then applied to the samples. This resulted in an increase in torque-load sensitivity (field signal in mG per unit applied shear stress in lb/in<sup>2</sup> or psi) from 48.2 microgauss/psi to 59.2 microgauss/psi in the A-2 sample and from 125 microgauss/psi to 189 microgauss/psi in the H-13 sample, as well as remarkably improved linearity of the signals and a more reliable re-zeroing of the sensors following removal of the applied torque. Simultaneously, the magnetic hysteresis properties of the samples were studied prior and subsequent to the heat treatments. The axial coercive forces were found to decrease in each case, with the percent of decrease in excellent correlation to the percent of increase in the sensitivities found above, while the circumferential coercive forces were sufficiently large to guarantee integrity of the magnetically polarized regions comprising the sensor. The width and magnetic intensity of the domain wall in each sensor were also measured using the technique of magnetic force microscopy (MFM).

5:10 - 6:00 Laboratory Tour - meet in hallway outside Olin 44

5:15 - 6:20 Cash Bar - Alumni Room in the Student Center

6:20 - 7:40 Banquet - Alumni Room in the Student Center  
Presentation of the *2004 Distinguished Service Citation* to  
Dr. Charles E. Schulz, Professor of Physics at Knox College

7:50- 8:50

**"Imaging Nanostructures in Motion"**

**Dr. Robert Nemanich**  
Physics Department, North Carolina State University  
Olin 168

Imaging nanostructures with real time microscopy techniques is crucial to developing understanding of the dynamics of the growth of nanostructures and nanostructure arrays. We have combined a high resolution electron emission microscope with the tunable light emission from a free electron laser. We will describe how image contrast is obtained by tuning the wavelength of the free electron laser, and we will present examples of nanostructure dynamics. Images will show nanoscale islands that move together, nanoscale liquid droplets that grow larger as they move, and nanoscale dots that transform to wires. The system can also be used to determine the properties of biological systems, and results on melanosomes will be displayed. Each example represents a complicated physical phenomenon.

*Saturday, October 16, 2004*

7:00 - 8:00 ISAAPPT Council meeting - Olin 24 Presiding: Mark Boley, President, ISAAPPT

8:00 - 9:00 Registration - Main Lobby, First Floor Entry, Olin Hall

8:30 - 9:30 Session C - Contributed Papers - Olin 168

Session Chair: Duane Ingram, Rock Valley College

8:30 - 8:45 - C1

**Experimental Investigation of Chaos in a Rotating Waterwheel.** *Valerie N. Hackstadt, Epaminondas Rosa, Jr., and George H. Rutherford*, Illinois State University, Normal, IL 61790. The Lorenz waterwheel is a well-known example of a simple mechanical system that exhibits chaotic behavior and can be described by the same set of equations discovered in Lorenz's pioneering study of chaos in atmospheric convection. It is surprising, however, that no experimental study of this mechanical analog of the Lorenz equations has ever been published, especially given the rich structure of the dynamics. In this talk, we described theoretical and numerical investigations of the waterwheel, leading to estimates of parameter ranges that seem suitable to the design of a working waterwheel. We then describe the experimental design in more detail, present preliminary data, and discuss a number of future experiments.

The wheel itself consists of a thin frame of vacuum-formed polycarbonate to which 36 cylindrical cells are attached, long axes perpendicular to the plane of the wheel, at about a 23 cm radius. The wheel is attached to a platform via bearings, and the platform can be tilted to an angle up to 45 degrees above the horizontal. Water is introduced through a metering flow valve into a manifold that allows the angular distribution of the input flow at the top of the wheel to be varied. The angular position of the wheel is measured with a shaft encoder interfaced to a multi-purpose data acquisition board in a desktop Macintosh computer. Numerical differentiation of the angular position time series data gives  $\omega(t)$ , and the other two Lorenz variables are not directly measured. Portraits of the strange attractor can be produced via time delay embedding of the  $\omega(t)$  data. One important element in the chaotic waterwheel is the introduction of dissipation in the form of a braking torque, preferably proportional to the angular speed. In the original Malkus design, built at MIT in the early 1970's, this braking was produced by a bushing containing viscous oil. Our design uses an eddy current brake consisting of a thin aluminum ring at the periphery of the wheel that passes between the pole faces of a variable gap magnet. The eddy current drag produces a torque proportional to the angular speed.

Measurements were made of the terminal velocity of a test wheel driven by a falling weight for various magnet gap spacings. These measurements were then used to determine the braking constant  $\nu$  ( $\tau = -\nu\omega$ ) as a function of the gap spacing. These data and other design specifications will be described. Preliminary data used to estimate the contribution from bearing friction will also be discussed. Finally, we discuss a range of future experiments to investigate, e.g., the effect of various angular distributions of the input water flow and possible synchronization of chaotic motion to a small sinusoidal disturbance.

**8:45 - 9:00 - C2**

**"45° or Bust"**. *Ann Brandon and Debby Lojkutz*, Joliet West, Joliet, IL 60435. Following in the tradition of Don Reid, we have a "Stomper" lab. Toys R Us is selling a battery powered car that claims to climb a 45° incline. We will demonstrate, and find its coefficient of friction.

**9:00 - 9:15 - C3**

**"Comparison of X-ray and Laser Photon Effects on Si (100) Surfaces Covered by Diethylsilane at 100 K"**. *Erika Crandall and Rachel Price, Jose Lozano, Kevin Kimberlin, James Craig and Paul Wang*, Bradley University, Peoria, IL 61606. X-ray photons from a Mg X-ray source and 4.67 eV photons from a Nd:YAG laser were used to irradiate diethylsilane (DES) covered Si (100) at 100 K. Two kinds of coverage of DES were applied at 100 K. One was 0.5 L which is physi-sorbed DES and the other was chemi-sorbed DES produced by heating the sample to 350 K and immediately cooling to 100 K. Preliminary results show that dominant C-C/C-H bonds increase under X-ray radiation but decreased under laser radiation on physi-sorbed DES. Consequently Si-C bonds are enhanced under X-ray exposure and reduced after laser exposure. Both C and Si species were modified after X-ray radiation but only C species were affected by 266 nm photon radiation on chemi-sorbed DES/Si (100) systems. Experimental results when using X-ray induced secondary electrons and 4.67 eV photons will be discussed.

**9:15 - 9:30 - Take Fives**

1. *Debby Lojkutz*, "Physics of the Olympics"
2. *Daniel Ludois*, "Wire Fryer Electricity and Magnetism Demonstration"

**9:30 - 10:00 Break with donuts - Olin 45**

**10:00 - 11:00 *"Improving Physics Teaching through Physics Education Research"***

**David E. Meltzer**

**Department of Physics and Astronomy, Iowa State University  
Olin 168**

Physics teachers are always striving to improve the effectiveness and efficiency of their teaching methods, and to find the best possible curricular materials to use with their students. In recent years, physicists have begun to turn this effort to improve instruction into a systematic research project. By carrying out careful investigations of student learning in physics, much insight has been gained into the teaching process. Based on this work, new curricular materials and instructional methods are being developed and tested. I will outline the goals and methods of this research, and describe its connection to learning in the classroom. With examples drawn from investigations we have carried out at Iowa State University, I will illustrate the research process and show how it can lead to improved instruction.

**11:00 - 12:00 Session D - Olin 168**

Session Chair: Carl Wenning, Illinois State University

**Report on the Special Pre-Session Workshop: "Repairing the Illinois High School Physics Teacher Pipeline"**, Carl Wenning, Kim Shaw, Ken Mellendorf, Steve Weber.

**12:00 - 1:00 Lunch and Business Meeting - Olin 45**

**1:00 - 1:50 Laboratory tour - meet in hallway outside Olin 44**

*Last update: October 16, 2004*

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