Physics Department

Professor Francis D. Correll
Chair

Physics Department faculty members were vigorously engaged in research and other scholarly activity during the 2000-2001 academic year. Their efforts helped them keep current in their various areas of specialization, allowed them to expand the use of research-based teaching techniques in our classrooms and laboratories, and provided opportunities for midshipmen to develop as independent scholars.

The reports that follow describe studies in such traditional areas of physics research as acoustics, astronomy and astrophysics, atomic physics, condensed matter physics, cosmology, nonlinear optics, nuclear structure physics, and planetary physics. They also relate work in a variety of interdisciplinary fields, including cognitive science, imaging and pattern recognition, ion beam analysis, materials science, optical communications and photonics, and radiation effects. Additionally, they describe important efforts to understand how students learn physics and how to teach it more effectively.

External research sponsors included the National Science Foundation, the Office of Naval Research, the Research Corporation, the Naval Research Laboratory, the Naval Surface Warfare Center, the Naval Air Warfare Center, the National Center for Physical Acoustics, and IBM Corporation. Internal support came from the Naval Academy Research Council.

Our faculty shared the results of their efforts by publishing scholarly articles and making presentations at conferences. This year, physics faculty members published one book, 11 articles in refereed journals, 6 articles in conference proceedings, and 11 articles on the Internet. In addition, they issued 4 faculty technical reports and 2 midshipman/faculty publications/technical reports. Finally, faculty and midshipmen made 37 presentations at conferences or workshops, including some at international meetings in Australia, Austria, Canada and Italy.

The relationship between the faculty and our students remained close and productive. One Trident Scholar, Midshipman 1/C Peter G. Brereton, USN, studied changes in the electrical properties of strontium barium niobate as it was illuminated with light from a tunable argon-ion laser. He received honorable mention in the competition for the annual Office of Naval Intelligence Harry E. Ward Trident Scholar prize. Two midshipmen developed successful new Trident Scholar proposals, which they will carry out during the next academic year. Eight midshipmen participated in research projects in acoustics, astronomy, and nuclear physics, and several of them gave talks at professional meetings.

Sponsored Research

Component Development for Free-Space Optical Communication

Researcher: Assistant Professor Mark L. Biermann
Sponsor: Naval Research Laboratory (NRL)

Free-space optical communication offers many appealing advantages over other forms of free space communication. This project was in support of several programs related to free space optical communication, all of which employ a modulating retroflector. The primary activity was the design and characterization of novel optical retro reflectors for potential use with modulators.

In order to meet design criteria for the modulating retro reflector systems being developed, the basic design chosen for the retro reflector was a modified, cat's-eye retro reflector. The cat's-eye system is catadioptric in nature, employing refracting elements, lenses, and a reflective element, a mirror. A commercial, optical-design, software package, Zemax, was employed in the design and characterization of the optical system. A number of promising optical designs for the retro reflector emerged. All consist of a concave mirror placed behind 2 or more lens elements. While flat mirrors can be used for systems that operate with

a full field of view of no more than a few degrees, concave mirrors provide significantly improved performance at large field angles. Systems consisting of three lens elements provide diffraction limited performance for an infinity f/# of about 1.7 over a full field of view of up to 25°. Systems consisting of four lens elements provide diffraction limited performance for an infinity f/# of about 1.7 over a full field of view of up to 30°. Advantageous placement of the aperture stop virtually eliminates vignetting losses in these systems.

Modeling Optical and Electronic Properties of III - V Quantum Well Structures

Researcher: Assistant Professor Mark L. Biermann
Sponsor: Naval Research Laboratory (NRL)

Quantum well structures provide excellent performance in a variety of electro-optical applications. The further characterization of these complex systems is beneficial to a greater understanding of the systems on a fundamental level and to gaining insight into additional device applications. The goal of this research is to provide a robust numerical model of a variety of quantum-well systems that can be applied to motivate and analyze experimental work related to quantum wells and their applications.

A k dot p, empirical pseudopotential method has been employed in developing the numerical model of quantum wells. The first segment of the formalism is now functioning on computers at the Naval Academy. This component involves the pseudopotential calculation for the bulk semiconductor materials being used in the quantum wells. Currently, the segment that brings together the results for the individual materials into specific quantum well arrangements is being constructed. This segment uses matching of the normal component of the current density matrix at the interfaces between the materials to calculate the bandstructure and envelope functions of the quantum well structure.

Nonlinear Optics in Capillary Waveguides

Researcher: Assistant Professor James J. Butler
Sponsor: Naval Research Laboratory (NRL)

This research involves the study of optical limiting in highly nonlinear capillary waveguides. As information data rates become larger and higher power lasers are used, protection of sensitive pieces of optical equipment becomes a necessity. Thus, devices that can limit the intensity of transmitted light and that are compatible with optical fibers will play a crucial role in the future development of these areas. Highly nonlinear capillary waveguides will provide low threshold optical limiting and will extend the wavelength range at which optical limiting in fiber optic systems can be achieved.

The plan of procedure for this research project is divided into two sequential steps: (i) preparation and characterization of glass capillaries with a linear core material and (ii) testing of the optical properties of glass capillaries with nonlinear core materials. Preliminary work on both of these steps began in the summer of 2000. This investigation is a continuation of that work.

Refinement of Global Planetary Magnetosphere Models

Researcher: Professor Irene M. Engle
Sponsor: Naval Academy Research Council (NARC)

The objective of this work is to incorporate a more realistic magnetotail model into the full range of global magnetospheric models of the Saturnian magnetosphere, in preparation for the Cassini spacecraft entry into polar orbits about Saturn.

Ensign Jeremy J. Bruch, (USN), (Trident Scholar, Class of 1999) solved a problem of incorporating a modified magnetotail model based upon the incident solar-wind direction versions of the Saturnian magnetosphere model during his 1998-99 Trident Scholar year. This research has expanded upon that initial work to have a full range of models for the total range of possible incident solar wind directions. A crucial next step was to modify the magnetotail models in such a way that their outer boundaries would meld with the boundaries computed from applying the magnetohydrodynamic principle of balanc-

ing the incident solar wind pressure on the boundary with the combined internal magnetic field pressure (+ some plasma pressure) inside the boundary. Many postulated modifications have been mathematically modeled and the resulting magnetospheric characteristics studied, and subsequently rejected. Although much progress has been made, there is not as yet a set of models which fully meet all of the criteria initially set by the investigator.

Properties of Fuel Cell and Battery Materials

Researchers: Associate Professor C. A. Edmondson, Professor J. J. Fontanella
and Professor Mary C. Wintersgill
Sponsor: Office of Naval Research (ONR)

The goal of the project is to provide basic studies of fuel cell and battery materials linking properties, structure and dynamics to performance. The primary scientific objective is to determine the ion transport mechanism in the materials. The technological goal is to improve fuel cell ion-exchange membranes and battery electrolytes. Investigations of low temperature proton conducting membranes will be completed where possible. This includes studies of the sulfonated polystyrene – poly(vinylidene fluoride) (PSSA-PVdF) developed and fabricated by the Jet Propulsion Laboratory (JPL) and the low methanol crossover materials developed by Pintauro and co-workers at Tulane. Work will also continue on ionic liquids ands molten salts. In addition, work will begin on high temperature (>100°C) proton conducting membranes including the development of associated experimental techniques.

Student Experiments during a Solar Eclipse

Researcher: Associate Professor James R. Huddle
Sponsors: Innovations in Travel, Texas Instruments and Vernier Software & Technology

A total solar eclipse presents an exciting opportunity to teach science to young people. A suite of experiments for this purpose has been under development since the 26 February 1998 eclipse in Aruba. Approximately $12,000 worth of donated and loaned equipment has been secured from Texas Instruments and Vernier Software. This equipment has been shipped to three schools in Zimbabwe and Zambia to be used during the 21 June 2001 eclipse. Students there will measure air and ground temperature, humidity, barometric pressure, and CO_2 concentrations, as well as light intensity levels and the flash spectrum.

Low Frequency Observations and Analysis of Radio Sources

Researcher: Associate Professor Debora M. Katz(-Stone)
Sponsor: Naval Research Laboratory (NRL)

We have collected data of radio galaxies, supernova remnants and other radio sources at extremely long-wavelengths. These data have been reduced with wide-field, three-dimensional algorithms, which are required for sensitive imaging of these long-wavelength observations.

These data were then analyzed using highly sensitive techniques. These results lead to in situ acceleration mechanisms, which call in to question the standard models for these sources.

Jet-Intracluster Medium Interactions of the Radio Galaxy 3C 129

Researcher: Associate Professor Debora M. Katz(-Stone)
Sponsor: Naval Research Laboratory (NRL)

The researcher was awarded observation time on the Very Large Array. Observations of the radio galaxy 3C 129 addressed two questions. First we estimated the non-thermal pressure for various radio components and thereby derived values of the internal energy densities. Second by making a detailed comparison between high quality radio data and x-ray data

obtained by CHANDRA (space-based observatory), we studied the signatures of hydrodynamic interactions between radio plasmas and the ambient cluster gas. 3C 129 provided a uniquely endowed source for this endeavor: it is nearby, it lies relatively far from the cluster center, it's long tail suggests that it lies mostly in the plane of the sky, and ram pressure is likely to be important only near the head.

Nonlinear Acoustics Experiments in the Application of Detection of Land Mines

Researcher: Professor Murray S. Korman
Sponsor: National Center for Physical Acoustics
(University of Mississippi, University, MS)

Nonlinear propagation of acoustic waves in soils, along with the nonlinear vibration of compliant buried objects is studied with application for the remote detection of buried land mines using low frequency sound.

Solid-State Laser Cooling of Organic Dyes in Modified Polymers

Researcher: Assistant Professor Carl E. Mungan
Sponsor: Research Corporation

The goal of this new multi-year research project is to laser cool a dye-doped solid polymer for the first time. To date, net optical cooling has only been achieved for three bulk materials: gaseous carbon dioxide, rhodamine dyes in liquid ethanol, and trivalent rare-earth ions in a heavy-metal-fluoride glass. These systems have drawbacks which have held back development of bulk laser cooling concepts. In view of recent progress in solid-state dye lasers, the time is ripe for a complementary experimental program in laser cooling of such materials.

From a basic physics point of view, the result of this project will be an improved understanding of large organic molecules doped in polymers. The measurement of relative laser cooling powers is the best way to quantify near-unity fluorescence quantum efficiencies. Improved photothermal measurement techniques will be developed for this purpose. In addition, the optimization of cooling involves investigation of chemical and structural impurities in the host, the nature of the dye molecular sites in the polymer, the extent of energy transfer to surrounding chromophores, and the determination of the relevant thermo-optic coefficients.

Beyond this basic scientific significance, the proposed research has two eventual technological applications. One is the development of a novel refrigerator for satellite infrared detectors. Current Stirling-cycle coolers are limited by their bulkiness and vibrations, while thermoelectric devices are hampered by poor efficiencies and high operating temperatures. The other application of optical cooling is to a new laser design. Conventionally, heat generation in the active medium leads to decreased performance because of thermally induced stresses, optical lensing, and chemical degradation of the dye molecules. This limits the power handling of solid-state lasers, especially in view of the low thermal conductivities of typical polymers. This internal heat generation could be eliminated by balancing the Stokes shift of the laser emission against the anti-Stokes shift of the spontaneous fluorescence. The broad bandwidth of dye lasers should make them an excellent experimental testing ground for this idea.

Development of Infrared Ytterbium:Vanadate Laser

Researcher: Assistant Professor Anne-Marie Novo-Gradac
Sponsor: Naval Air Warfare Center, Aircraft Division (NSWC-AD)

Currently there are numerous civilian and military applications for the neodymium doped yttrium aluminum garnet laser (Nd:YAG). This laser operates at 1064 nm with wall plug efficiencies ranging from 3 to 10%. The purpose of this research project was to investigate the viability of ytterbium doped yttrium vanadate ($Yb:YVO_4$) as a competitive laser material to Nd:YAG. Our earlier work had predicted that $Yb:YVO_4$ would produce laser emission around 1030 nm with wall plug efficiencies approximately four times greater than Nd:YAG. This would have substantially reduced the expense and bulk of such laser systems. Unfortunately, our more recent work has indicated that $Yb:YVO_4$ is unlikely to achieve this goal.

Experiments conducted during the summer of 1999 focused on measuring the spectral characteristics of Yb:YVO_4, and developing rate equation models to predict laser performance. During the summer of 2000 efforts were focused on designing and building a working laser. Additional spectroscopic data was taken as needed.

Three different laser cavities were attempted and YVO_4 samples of Yb concentration ranging from 0.8 to 4.0 atomic percent were used. The system was pumped using a Ti:Sapphire laser producing up to 350 mW. Cavity resonance was achieved, but laser action was not. This indicates that the cavity design was adequate to the task, but that the material itself was not. We are currently trying to determine why Yb:YVO_4 has failed to produce laser action. There are four principal possibilities, each of which is being addressed.

The first possibility is that the pump power delivered to the crystal is inadequate to reach threshold. We are attempting to gain access to a more powerful pump laser. A second possibility is that Yb:YVO_4 is more suited to pulse operation rather than continuous wave (CW) . The rate equation models produced during the summer of 1999 predicted that pulse laser action in Yb:YVO_4 was unlikely. A third possibility is that the Yb dopant concentrations chosen are not appropriate for producing laser action. If the dopant concentration is too low there are insufficient ions to sustain laser action. If the dopant concentration is too high the pump laser is not uniformly absorbed along the optical path and emitted light is self absorbed by the Yb:YVO_4, preventing laser action. Given the range of concentrations attempted during the summer of 2000, we believe that concentrations below 0.8% should be investigated.

The last possibility is that the energy level structure and transition probabilities in Yb:YVO_4 will not permit laser action at room temperature. Although the rate equation models produced during the summer of 1999 predicted that laser action could be achieved, the models may have not have been sophisticated enough to consider thermal loss mechanisms that may be preventing laser action. Efforts are underway to take more detail into account in these models to determine the conditions preventing laser action.

Although we are disappointed by these results, they are important nonetheless. A greater understanding of the conditions necessary to produce laser action in similar materials has been achieved and other candidate materials can now be screened more efficiently.

Cooperative Ferromagnetic Hysteresis in Transition Metals

Researcher: Professor Carl S. Schneider

Sponsors: Office of Naval Research (ONR) and Naval Surface Warfare Center (NSWC)

Precise experimental data suggesting that domains cooperate in ferromagnetic hysteresis is presented. This model has potential applications in magnetostrictive transducers, transformer design, magnetoelastic effects and hysteresis in general. For an annealed three per cent nickel steel alloy, we measured magnetic induction from the demagnetized state to near saturation, the reversal to near saturation and return branches from both these curves. Modeling variables include the coercive field, saturation magnetization, initial susceptibility and the hysteresis effective field. Magnetization is scaled to its saturation value and magnetic field to its coercive value in the direction of field change, and susceptibility is scaled to its reversible function. Scaled differential susceptibility increases from its reversible value exponentially with magnetization change from any reversal and decreases exponentially with decreasing slope to its reversible value at saturation. We define the slope of this exponential to be a hysteresis constant divided by the scaled effective field, and this dimensionless field is the square root of two for hysteresis loops of polycrystalline domains with fully nucleated walls. Rayleigh's hysteresis constant, valid for heavily worked steels and small fields, transforms to our cooperative hysteresis constant at larger fields. For the saturate curve, the scaled effective field reaches a minimum less than one near the coercive field before domain interactions increase through wall nucleation and their local fields. Variation in the effective field causes hysteresis loops to creep upon cycling.

Andes2: A Help-Oriented Intelligent Tutoring System

Researchers: Professor Kay G. Schulze (Computer Science Department),
Professor Robert N. Shelby, Professor Donald J. Treacy,
Professor Mary C. Wintersgill, (Physics Department) and Kurt VanLehn (University of Pittsburgh)
Sponsor: Office of Naval Research (ONR)
Cognitive, Neural and Biomolecular Science and Technology Division

The Andes project is developing an intelligent tutoring system for teaching physics to students at the U.S. Naval Academy. It is based on three key ideas: (1) it should help students with their physics homework rather than replace classroom instruction, (2) several types of help systems are necessary for effective learning, and (3) principle-based dialog between the students and ANDES is an effective method to give useful advice as a tutor. Andes covers a fairly complete version of the first semester of a of college physics. The project has conducted several evaluations at the Naval Academy and in laboratories at the University of Pittsburgh. The current research is expanding the scope of the tutor, seeking to increase its acceptance at the Academy and conducting several types of evaluations in order to measure and increase the effectiveness of the tutor. ANDES is being cast in a new form to allow the tutor to give better diagnostic advice to the student. This version should be ready for a trial in the fall semester of 2001.

Applied Studies of the Imaging and Pattern Recognition

Researcher: Professor L. L. Tankersley
Sponsor: Naval Research Laboratory (NRL), Code 5614

All the studies conducted in this research are in support of an ongoing effort at the Naval Research Laboratory in Code 5614. Under this sponsorship, the current studies focus on optical detection and analysis of debris in turbine engine lubrication fluids, with imaging through turbid media. The emphasis on monitoring operational systems is to be increased. Theoretical background areas including quantum optical effects are to be studied to understand fundamental limitations on approaches to noise reduction in optical imaging schemes.

1. Collect field samples data and compare evaluation schemes.
2. Optical evaluation of lubricating fluids using partial-volume sampling.
3. Optical studies of small wear particles in lubricants.
4. Real-time evaluation of debris in turbine engine lubricants.
5. Software development for system integration.
6. Development of support electronics.
7. Signal to Noise effects due to amplification and attenuation.
8. Theoretical investigation of non-linear effects involving longitudinal fields.

Nuclear Structure of Tellurium-126, -128, and -130

Researcher: Professor Jeffrey R. Vanhoy
Sponsor: National Science Foundation (NSF)

Tellurium has a wide range of abundant stable isotopes. Three different types of structure are thought to be active in these nuclei: collective, two-particle, and particle-hole excitations known as intruders. Because there are seven stable even-even Te nuclei, one can study the evolution of these excitation modes over a wide range in neutron number. Emphasis centers on understanding the interplay between particle and collective features and on the aspects of the nuclear forces that determine the relative importance. In the tellurium nuclei several models are now able to reproduce the level scheme, however level lifetimes and transition rates are needed to further examine the detailed components of the wavefunctions.

Excited levels in ^{126}Te, ^{128}Te and ^{130}Te below 3.3 MeV are being studied at the University of Kentucky Nuclear Structure Laboratory utilizing inelastic neutron scattering techniques. Electromagnetic transition rates, multipole mixing and branching ratios, and level spins and parities can be deduced from measured gamma-ray excitation functions, $\gamma\gamma$ coincidences, angular distributions, and Doppler shifts.

Investigation of the Natural Neutron Environment

Researchers: Visiting Professor James F. Ziegler and
Professor Martin E. Nelson (Mechanical Engineering Department)
Sponsor: International Business Machines, Inc. (IBM)

This project involves research in determining the spectrum of neutrons and their energies at terrestrial altitudes.

Independent Research

Intermediate Velocity Clouds

Researchers: Professor C. Elise Albert and L. Danly, University of Denver

Since we wrote, last year, an invited chapter on Intermediate Velocity Clouds for the book "High Velocity Clouds" (to be published by Kluwer Academic Press), major new advances in the field have necessitated, this year, significant revisions and additions to the original work.

Intermediate Velocity Clouds (IVCs) refer to dynamically significant gas in the Milky Way galaxy with velocities outside the range that can be ascribed to normal galactic rotation, but not so extreme (<100 km/s) as to be considered High Velocity Clouds. This phenomenon may include material accelerated in supershells, recycling in a galactic fountain, or infalling from outside our galaxy. The study of IVCs has progressed both from direct radio detection of intermediate velocity neutral hydrogen gas in emission at 21 cm and optical and ultraviolet observations of trace elements seen in absorption at these velocities toward distant stars. For this review, we gathered and organized all the relevant observations from the literature and reviewed our ongoing work in this field and the contributions of other researchers.

Variable Star Studies

Researcher: Professor C. Elise Albert

The researcher has begun background research into the field of variable stars. The magnitudes and colors of certain classes of stars can change for a variety of reasons, including pulsations or other instabilities, rotation of "star spots", mass exchange or eclipses with a companion star. Several of these phenomena may be suitable for study with the CCD camera system and 20 inch reflecting telescope on the roof of Michelson Hall.

Determination of the Temperature of the Sun on a Cloudy Day

Researchers: Assistant Professor Mark L. Biermann
and the students in an SP 324 class, Spring 2001

It is well known that the temperature of the sun can be determined from its optical spectrum by modeling the sun as a blackbody radiator. The temperature can then be determined by finding the peak wavelength of the sun's effective blackbody radiation curve and applying Wien's Displacement Law. The question of interest was whether this method could be applied equally well on cloudy days and sunny days. That is, do clouds alter the spectrum of the sun in such a way as to render inappropriate the standard method described above?

We used an Ocean Optics UV-VIS spectrometer as our principle instrument for data collection. We compared spectra and the calculated temperature of the sun on several days. After repeated analyses we found that the clouds do not interfere with the method for finding the temperature of the sun. While the overall intensity of the sun's radiation incident at ground level is lower on a cloudy day, the key feature, the gross spectrum of the sun, is not significantly altered. The clouds act to scatter the light from the sun uniformly across all visible wavelengths, preserving the location of the peak. This result is especially of note for teaching laboratories, where the weather at a given class meeting time is not known when a syllabus is written.

Optical Properties of Birefringent Volume Gratings

Researcher: Assistant Professor James J. Butler

An optical beam steering element is a device that is used to control the direction in which a beam of light travels. The researcher has investigated the optical properties of a class of beam steering elements that utilize the fact that the amount of light diffracted by a hologram imbibed with a nematic liquid crystal can be controlled by the application of an electric field. By a careful comparison of experimental data and theoretical predictions it has been shown that the birefringence of the liquid crystal must be included in order to correctly model these devices. This ongoing work will also provide evidence of the orientation of the liquid crystal within the diffraction grating thereby leading to a better understanding of the physics of these structures.

Global Planetary Magnetosphere Boundary Representations

Researcher: Professor Irene M. Engle

An ongoing difficulty of making sophisticated magnetospheric models optimally useful in applications is adequately specifying the region of applicability. A well-developed mathematical model essentially constructs its own domain if a sufficient number of magnetic field lines, which are "footed" on the planet surface, are traced. None of the lines will go beyond what is known as the magnetopause, the boundary to the local magnetosphere. Unfortunately, in general, a mathematical model will also readily permit the tracing of field lines started points outside the model, but these lines, and the magnitudes and directions of the magnetic fields at locations along them are entirely irrelevant. When a position r(¸$) or, alternatively (x,y,z) is specified, it is helpful to know whether that spatial location is inside or outside the magnetopause boundary. The goal is to be able to specify an R(¸$) representing maximum r from the planet along a particular spatial direction (¸$). Since the original calculation of the magnetopause is generally done via an angular grid and the shapes, especially where magnetotails are incorporated, are not at all simple (e.g., R = Ro would represent a sphere).

Although the near-planet magnetosphere can be in some cases considered to be a misshapen sphere with dimples on the side facing the solar wind, the extended magnetotail on the side away from the solar wind is more closely approximated by a elliptical cone, which expands as one is further away from the planet. Sufficiently accurately representing the boundaries is an ongoing challenge for assorted magnetospheric models of three planets, i.e., Mercury, Jupiter, and Saturn.

Developing a Temporal Model for the Dynamics of Multiply Connected One-Dimensional Systems

Researchers: Associate Professor John P. Ertel
and Joseph W. Dickey, Material Science and Engineering Department,
Johns Hopkins University, Baltimore, MD

Connected one-dimensional systems can be used to model a variety of complex dynamic systems; for example layered media, macroscopic and microscopic structural networks, and any canonical object in which the wave equation is separable. The temporal model being developed here would describe the reverberation of transients in these systems. Temporal descriptions are generally derived from frequency domain models via Fourier transform, which requires the structure to be stationary in time. In contrast to this, the current model is derived entirely in the time domain and can therefore incorporate boundary conditions that change in time.

Nonlinear Scattering Of Crossed Ultrasonic Pulsed Beams In The Presence Of Turbulence: Doppler Shift And Spectral Broadening Effects

Researcher: Professor Murray S. Korman

The nonlinear scattering of two finite-amplitude mutually perpendicular crossed CW beams - interacting in the presence of turbulence - generates a sum frequency component that radiates outside the interaction region. [Korman and Beyer, *J. Acoust. Soc. Am.*, Vol 84, pp.339-349 (1988) and Vol 85, pp. 611-620 (1989)]. Their theoretical results are now extended to predict the angular dependence of Doppler shift and spectral broadening when the incident primary wave components are plane wave pulses instead of continuous waves. Starting with Lighthill's equation, the Born approximation is used to find the scattered density field Ás(**x**,t) at the sum frequency. Modeling isotropic turbulence (with Gaussian statistics) that is stationary in time, homogeneous in space and "locally frozen", one obtains the ensembled average Fourier spectrum. (Details of the mathematics are available from the researcher.)

Calcium Concentrations in Specimen Bottle Glass from the Darwin Expedition

Researchers: Professor Jeffrey R. Vanhoy and Pam Vandiver (Smithsonian Institution)

Glass chards were recovered from Pacific islands visited by the Charles Darwin expedition of the 1830's. The composition of this glass was analyzed at the Naval Academy Accelerator Laboratory's Pelletron Accelerator with the Proton-Induced X-Ray Emission (PIXE) technique. The trace element composition of glass can indicate its usage and preparation technique. The sample was found to be representative of specially made specimen bottles but with an anomalously high calcium concentration. This high concentration indicates that a special firing and quenching technique was used to manufacture the bottles.

Visual Survey for Local Group Dwarf Galaxies

Researcher: Commander A. B. Whiting, USNR

Dwarf galaxies are central to theories of galaxy formation and shed important light on star formation, and in addition act as tracers of dark matter. Extremely low-luminosity dwarfs are only detectable at very short distances, in effect in and near the Local Group of galaxies. A visual search of southern sky photographic survey plates has resulted in a list of candidate Local Group low-luminosity dwarf galaxies. Follow-up observations have confirmed two as previously unknown members of the local Group, four as nearby dwarfs just outside the Group and about forty as more distant low-luminosity galaxies. A search of the northern sky plates has resulted in a list of about one hundred similar candidates. Follow-up observations of these are in process.

The Hubble Tensor: Velocity Anisotropy In The Local Volume

Researcher: Commander A. B. Whiting, USNR

Within the Local Volume of about 10 megaparsecs (Mpc) the galaxy distribution is strongly anisotropic. One would therefore expect the distribution of radial velocities to conform, showing a smaller increase with distance (component of the Hubble tensor) in the most flattened direction, to a degree which depends on the concentration of dark matter on this scale. A least-squares fit to data for 67 galaxies within this volume does indeed show anisotropic flow, with the largest Hubble component roughly four times the smallest. However, further analysis shows that this effect is largely or entirely due to theanisotropic distribution of the galaxies themselves, along with noise in the data. A set of 25 galaxies chosen for better quality data shows a similar effect. A list of galaxies is constructed for which good distance determinations would help the situation greatly.

Sir James Jeans and Stellar Instability

Researcher: Commander A. B. Whiting, USNR

In the late 1920s Sir James Jeans calculated that gaseous stars whose power source was sensitive to pressure and temperature would be violently unstable, and constructed a theory of essentially liquid stars powered by a form of radioactive decay. The flaw in his calculation has apparently never been found, although different approaches have come to different (and more correct) conclusions. A detailed examination of his mathematical reasoning reveals how careful one should be about simplifying assumptions, using one's physical intuition, and the nature of perturbation problems. The calculation done correctly allows some physical insight into the internal dynamics of stars.

The Stopping and Range of Ions in Matter

Researcher: Visiting Professor James F. Ziegler

The theoretical stopping and range of ions in matter is being modeled for applications such as for the semiconductor industry (both ion implantation and sputter deposition), material analysis using ions beams (RBS, PIXIE, ERD, NRA, etc.), radiation damage, nuclear weapon design, nuclear physics research, etc.

Research Course Projects

Optical Observations of Near-Earth Asteroids

Researchers: Midshipman 1/C Brooke Massie, USN and Midshipman 1/C Aaron Fielder, USN
Adviser: Associate Professor Debora M. Katz(-Stone)

Following the work of Trident Scholar Douglas T. Campbell (Class of 2000), the researchers used the 20-inch reflecting telescope of the roof of Michelson Hall at the U.S. Naval Academy to observe Near-Earth Asteroids. They tracked several asteroids during the entire academic year. These data were then submitted to the Minor Planet Center in order to calculate their orbits in order to determine if they pose a threat to the Earth.

In addition, the two student researchers teamed up with Dr. Richmond at the Rochester Institute of Technology to perform simultaneous observations of an especially close asteroid. With these data, they were able to directly measure the distance to the asteroid using the parallax method.

Nonlinear Scattering of Crossed Ultrasonic Beams in the Presence of Turbulence: Experiments Performed with Pulses

Researchers: Midshipman 1/C Rebecca Allison Manry, USN
and Midshipman1/C Lauren Majchrzak, USN
Adviser: Professor Murray S. Korman

The nonlinear scattering of two finite-amplitude mutually perpendicular crossed beams - interacting in the presence of turbulence - generates a sum frequency component that radiates outside the interaction region. Experiments are reported where two primary pulsed (f_1=2.35 MHz and f_2=1.65 MHz) focused beams are generated by 2.54 cm diam concave spherical transducer units (T_1 and T_2) of focal length 14 cm. The 4 MHz receiving unit ® is a 2.54 cm diam circular plane array. The turbulence is generated by a D=0.635 cm diam submerged circular water jet (nozzle exit velocity 7 m/s) whose orifice is located at 56D from the interaction region. All transducer beam axes and jet axis form a common plane. A scattering region is formed at the intersection of the focal points of the primary beams. While T_1 and T_2 rotate on radius arms - always keeping the beams

perpendicular - R is fixed. Symmetry suggests a scattering angle θ_*, , where $\theta_* = 0$ defines forward scattering. Ensemble averaged rms pressure spectra (near the sum frequency) are measured (1) as a function of angle and fixed pulse duration Ä ð=100 µs ð, and (2) at $\theta_* = 0$ and variable Ä ð ðin an effort to compare spectral broadening with our theory.

Nonlinear Scattering of Crossed Ultrasonic Beams in the Presence of Turbulence: Experiments Performed with Continuous Waves

Researcher: Midshipman 1/C Rebecca Allison Manry, USN
Adviser: Professor Murray S. Korman

The nonlinear scattering of two finite-amplitude mutually perpendicular crossed beams - interacting in the presence of turbulence - generates a sum frequency component that radiates outside the interaction region. Experiments are reported where two primary cw (f_1=2.35 MHz and f_2=1.65 MHz) beams are generated by 2.54 cm diam transducer units (T_1 and T_2) of focal length 14 cm. The 4 MHz receiving unit ® is a 2.54 cm diam circular plane array. Turbulence is generated by a D=0.635 cm diam submerged water jet (exit velocity 7 m/s) whose orifice is 56D from the interaction region. All transducer beam axes and jet axis form a common plane. The ensemble averaged spectrum (near 4 MHz) is measured (using a Tektronix digital oscilloscope) as a function of the "symmetry" scattering angle θ_* . After transferring the data to a computer, "notebooks" in Mathematica are developed to curve fit the Doppler shift $<f_d>$ and the n= 2nd, 3rd and 4th spectral moments $<(f - <f_d>)n>$ vs θ_* to the theory in an effort to measure the mean flow and turbulent velocity correlation functions of the turbulence. [Korman and Parker, in *13th ISNA, Bergen 1993, Advances in Nonlinear Acoustics*, Ed. H. Hobaek, World Scientific, p.650-655]. For example for n=2, 2nd order correlations $<v_x^2>$, $<v_x v_y>$ and $<v_y^2>$ can be measured.

Competing Structures in Tellurium-126

Researcher: Midshipman 1/C James A. Tanyi, USN
Adviser: Professor Jeffrey R. Vanhoy
Sponsor: National Science Foundation (NSF)

The excited levels of ^{126}Te have been studied using the (n,n'³) reaction at the University of Kentucky's CN Van de Graaff Laboratory. Gamma-ray excitation functions and angular distributions were measured for transitions from levels up to 3.34 MeV excitation in ^{126}Te. Analysis of the excitation function data have identified 25 excited states of spin J=0-6, previously unknown.

Applications of the Geometric Collective Model to Tellurium-126

Researcher: Midshipman 1/C James A. Tanyi, USN
Adviser: Professor Jeffrey R. Vanhoy
Sponsor: National Science Foundation (NSF)

The excited levels of the stable even-even tellurium nuclei have been examined from the viewpoint of the Gneuss-Greiner formulation of the General Collective Model. The potential energy surfaces obtained are generally consistent with spherical vibrational nuclei but show a slight tendancy toward prolate deformation. Any deformation minima are shallow. Application of the Gneuss-Greiner form of the potential to the ground state, first excited state, quadrupole triplet, and several of the 3-phonon states did not reveal the deformed shape with gamma soft character reported using the Dynamic Deformation Model potential. It remains to be seen if that interpretation was the result of including particle-like states (specifically the 6^+, 8^+) which are known to lie outside the GCM model space.

Doppler-Shift Lifetime Measurements in Tellurium-126

Researcher: Midshipman 3/C Tyler H. Churchill, USN
Adviser: Professor Jeffrey R. Vanhoy
Sponsor: National Science Foundation (NSF)

This project involved travel to the University of Kentucky Nuclear Structure Laboratory during the period 25 June – 05 July. The experiment used the 7 MegaVolt Van de Graaff accelerator to generate a neutron beam. These neutrons were scattered from an enriched tellurium-126 metallic target to study the excited states of that nucleus. Gamma rays emitted from the ^{126}Te nuclei were detected.

The researcher assisted in the preliminary servicing of the particle accelerator, construction of the experimental area, and sitting shifts during the experiment. His duty during the experiment was to analyze detector calibrations and monitor the detector and electronics for gain drift. Fortunately very little drift was observed. However, it was discovered that the EG&G Ortec AD114 ADC used for digitizing detector pulses has a high degree of non-linearity which is not describable by a simple polynomial fit. As a result, detector calibrations equations are now done in a piecewise fashion.

Trident Scholar Report

Complex Impedance Studies of Optically Stimulated Strontium Barium Niobate

Researcher: Midshipman 1/C Peter G. Brereton, USN
Advisers: Assistant Professor Charles A. Edmondson and
Associate Professor Steven R. Montgomery

The complex permittivity and impedance of undoped and unpoled single crystal strontium barium niobate (SBN) were measured with a computer interfaced impedance analyzer over a frequency range from 100 millihertz to 10 kilohertz using small AC signals with millivolt amplitudes. The think (~2 mm) planar crystal sample was placed between the plates of a modified parallel plate capacitor and illuminated on the side with linearly polarized argon-ion laser light operating at select wavelengths in the blue-green with photon energies that are slightly below the bandgap energy of SBN. Impedance spectra were obtained in the dark between room temperature and 70^{0}C and compared with impedance spectra obtained with laser illumination and no heating except that produced by absorption of the laser light. Dark measurements at all temperatures are consistent with studies in the literature that suggest electron hopping as the predominant charge transfer mechanism. Illumination markedly changed the conductivity of the crystal and the charge transfer mechanism. Illumination markedly changed the conductivity of the crystal and the charge transfer mechanism by elevating significant numbers of charge carriers in the conduction band. This was found to be independent of the polarization of the light and slightly dependent on its wavelength over our wavelength range of 458 nm to 515 nm. The dielectric constant of the crystal under illumination changed less than twenty per cent and is probably due to the slight heating of the crystal induced by the laser.

Publications

Journal (Refereed) Manuscripts

BIERMANN, Mark L., Assistant Professor and Nelson, Nicholas A., "Using the GPS to Determine the Size of Earth," *The Physics Teacher*, Vol 38 (Sept. 2000), pp. 360-361.

The global positioning system (GPS) has found a variety of applications beyond its original intended use. In this paper we study the application of the GPS to the problem of finding the size of Earth. The key to this experiment is the fact that GPS receivers provide position data in a number of formats. By applying results in the latitude and

longitude system and results in the Universal Transverse Mercator (UTM) system, one is able to calculate the size of Earth using the simple arc length formula. That is, by using the angular data provided by the latitude and longitude reading, and the arc length data provided by the UTM reading, one can calculate the radius of Earth. Our result was 6349 km, which is within 0.5% of the nominal value.

This technique is appealing for teaching laboratories. It provides excellent results with simple mathematics and data collection. It also provides an excellent format for discussing the difference between accuracy and precision in experimental data.

BIERMANN, Mark L., Assistant Professor, "How Bad Photographs Can Provide Good Optics Education Opportunities," *Optics & Photonics News*, Vol 12 #5 (2001), pp. 18-19.

The article discusses the use of photographs that "didn't turn out" as a basis for illustrating important optical phenomena. Since photography is popular, photographs are a natural means of communicating various optical phenomena to students and the non-specialist. The paper discusses approaches that can be used in presenting optical phenomena including reflections off of refracting surfaces, reflections off of film, antireflection coatings, diffuse and specular reflections, the visible spectrum, color response of film and the human eye, response time of cameras and the human eye, and depth of field. A detailed discussion of the phenomena of "flare" in lenses and reflections off of photographic film is presented. Photographs that illustrate these phenomena are included with the paper. Suggestions for applying photographs in optics education are given as well.

Bowman, S.R. and MUNGAN, C.E., Assistant Professor, "New Materials for Optical Cooling," *Applied Physics B*, 71 (Dec. 2000), pp. 807–811.

Well-characterized solid-state laser materials are evaluated for performance in optical refrigeration as well as radiation-balanced laser systems. New figures-of-merit are developed and applied to ytterbium doped materials. Superior performance is predicted for high cross section tungstate materials. Photothermal deflection experiments on samples of Yb^{3+} doped KGd(WO4)2 confirm anti-Stokes fluorescence cooling. This is the first observation of optical cooling in a crystal.

EDMONDSON, Charles A., Associate Professor, FONTANELLA, John J., Professor, Chung, S. H., Greenbaum, S. G., and Wnek, G. E., "Complex Impedance Studies of S-SEBS Block Polymer Proton-Conducting Membranes," *Electrochimica Acta*, 46, pp. 1623-1628, (2001).

Water uptake, swelling, ^{1}H pulsed gradient spin-echo nuclear magnetic resonance (NMR) and variable temperature and pressure complex impedance/electrical conductivity studies have been carried out on sulfonated styrene /ethylene-butylene /styrene (S-SEBS) triblock polymer proton conducting membrane. All of the data show different characteristics above and below about 10 wt-% water. For example, the diffusion coefficients, D from NMR and $D_{sð}$ calculated from conductivity data (which are the same to within experimental uncertainty), show different dependence on water above and below about 10 wt-% At high water content, the properties of S-SEBS are similar to those for Nafion 117, proton transport being similar to that in bulk water. For low water contents, however, the materials are different. For low water content S-SEBS, the variation of the conductivity with temperature is Arrhenius while that for Nafion 117 is not. The variation of the electrical conductivity with pressure gives rise to activation volumes on the order of 14 cm3/mol while those for Nafion 117 are about four times larger. These results indicate that proton transport in low water content S-SEBS occurs via a thermally activated process (ion motion via energy barriers), which is consistent with the rigid side chains in that material.

EDMONDSON, Charles A., Associate Professor, Stallworth, P.E., Chapman, M. E., FONTANELLA, J. J., Professor, WINTERSGILL, M. C., Professor, Chung, S. H., and Greenbaum, S. G., "Complex Impedance Studies of Proton Conducting Membranes," *Solid State Ionics*, 135, July 2000, pp. 419-424.

Complex impedance studies have been carried out on Dow 800, Dow 1000 and Nafion 117 membranes at various water contents and a variety of temperatures and hydrostatic pressures. At room temperature and pressure the usual gradual decrease in electrical conductivity with decreasing water content is observed. For very low water content materials the variation of the conductivity with pressure from 0 to 0.2 GPa (2 kbars) is large and gives rise to apparent activation volumes, _V, as large as 54 cm^3/mol. In addition, for low water content materials, there is a tendency for smaller equivalent weights (same side chains) or larger side chains to have larger activation volumes. At high water content, _V is relatively independent of the host polymer and negative values are observed at the highest water contents. These results provide support for the model where proton transport in high water content sulfonated fluorocarbons is similar to that for liquid water. All results are explained qualitatively via free volume. Ambient-pressure, variable-temperature ^2H T_1 and linewidth measurements imply a heterogeneous environment of the water molecules. Proton pulsed field gradient NMR studies in saturated Dow membranes verify the expectation that ionic conductivity is determined primarily by diffusion of water molecules.

FONTANELLA, J. J., Professor, BENDLER, J. T., Associate Professor, and WINTERSGILL, M. C. Professor, "Effect Of High Pressure On The Electrical Conductivity Of Ion Conducting Polymers," *Electrochimica Acta*, 46 (2001) 1615-1621.

Complex impedance and differential scanning calorimetry (DSC) studies have been carried out on poly(propylene glycol) (PPG) with an average molecular weight of 1025 and poly(ethylene glycol mono-methyl-ether) (PEG) with an average molecular weight of 350, both containing $NaCF_3SO_3$ in an approximately 20:1 ratio of polymer to salt. The impedance studies were carried out over a range of frequencies, temperatures and pressures. As expected, PEG:$NaCF_3SO_3$ exhibits the tendency to crystallize while PPG:$NaCF_3SO_3$ is a glass-forming liquid. The fit to the zero pressure data for PPG:$NaCF_3SO_3$ using a recently developed generalized Vogel equation is better than that for the standard VTF equation while for PEG:$NaCF_3SO_3$ the two expressions give about the same level of fit to the data. In the theory, the critical temperature, T_c, is allowed to vary with pressure. In addition, the defect-defect separation is assumed to follow the dimensions of the material. It is found empirically that the pressure dependence of T_c is similar to the pressure dependence of T_g for structurally related polymers containing no salt. Thus, the difference in the pressure dependence of the conductivity for PEG:$NaCF_3SO_3$ and PPG:$NaCF_3SO_3$ is attributed primarily to the difference in the pressure dependence of T_g. However, the details of the relationship between T_c and T_g remain to be determined.

SCHNEIDER, Carl S., Professor, "Domain Cooperation in Ferromagnetic Hysteresis," *Journal of Applied Physics*, 89 (2001), pp.1281-1286.

Precise experimental data suggesting that domains cooperate in ferromagnetic hysteresis is presented. This model has potential applications in magnetostrictive transducers, transformer design, magnetoelastic effects and hysteresis in general. For an annealed three per cent nickel steel alloy, we measured magnetic induction from the demagnetized state to near saturation, the reversal to near saturation and return branches from both these curves. Modeling variables include the coercive field, saturation magnetization, initial susceptibility and the hysteresis effective field. Magnetization is scaled to its saturation value and magnetic field to its coercive value in the direction of field change, and susceptibility is scaled to its reversible function. Scaled differential susceptibility increases from its reversible value exponentially with magnetization change from any reversal and decreases exponentially with decreasing slope to its reversible value at saturation. We define the slope of this exponential to be a hysteresis constant divided by the scaled effective field, and this dimensionless field is the square root of two for hysteresis loops of polycrystalline domains with fully nucleated walls. Rayleigh's hysteresis constant, valid for heavily worked steels and small fields, transforms to our cooperative hysteresis constant at larger fields. For the saturate curve, the scaled effective field reaches a minimum less than one near the coercive field before domain interactions increase through wall nucleation and their local fields. Variation in the effective field causes hysteresis loops to creep upon cycling.

SCHULZE, Kay G., Professor (Computer Science Department), SHELBY, Robert N., Professor, TREACY, Donald J., Professor, WINTERSGILL, Mary C., Professor and VanLehn, Kurt, "Andes: An Active Learning, Intelligent Tutoring System for Newtonian Physics," *Themes in Education*, 1:2, pp.115-136, 2000.

Andes is an intelligent tutoring system that allows students to solve physics problems in an environment that provides visualization, immediate feedback procedural help, and conceptual help. It currently tutors students in static forces, translational and rotational kinematics, work and energy, and linear and angular momentum. The system encourages the student to draw free body diagrams, when appropriate, and enter the equations necessary to solve the problem. It allows them to ask for hints, both in terms of what they have done incorrectly as well as when they have reached an impasse and do not know how to proceed. Andes has been used with a limited number of students at the United States Naval Academy with statistically significant results.

SCHULZE, Kay G., Professor (Computer Science Department), SHELBY, Robert N., Professor, TREACY, Donald J., Professor, WINTERSGILL, Mary C., Professor, VanLehn, Kurt, and Gertner, A., "Andes: An Intelligent Tutor for Classical Physics," *The Journal of Electronic Publishing*, University of Michigan Press, www.press.umich.edu/jep/06-01/schulze.html.

Natural Sciences are an essential component of the liberal arts educational experience. However, many students find the problem solving skills that are an integral part of any introductory physics course difficult to develop. In particular, working on homework assignments without the benefit of expert feedback is often a frustrating experience. In order to alleviate this situation, one possible remedy is to construct an intelligent tutoring system that is capable of providing immediate feedback and relevant hints to students. One such system is Andes, a coached learning environment for classical physics that has been in development.

VANHOY, J.R., Hicks, S.F., Warr, N., Alexander, G.K., Aubin, C.A, Burkett, P.G., Burns, M.C., CHAMPINE, B.R., Midshipman, 1/C, USN, COLEMAN, R.T., Midshipman, 1/C, USN, Collard, C.J., Corminboeuf, F., Crandell, K.A., Etzkorn, S.J., Garrett, P.E., Genilloud, L., Jolie, J., Kern, J., Shenker, J.L., Sklaney, B.K., TANYI, J.A., Midshipman 1/C, USN, Walbrun, M.M., and Yeh, M., "Coexisting Structures in the $^{120\text{-}124}$Te Nuclei," *Heavy Ion Physics*, 12, 287 (2001).

The level schemes of the mid-shell tellurium nuclei, A=120-124, have been developed utilizing in-beam ^{3}-ray spectrosopy following the (n,n'^{3}) and (±,2n^{3}) reactions and Iodine beta decay. Excitation functions, ^{3}-^{3} coincidences, and angular distributions were measured. Spectroscopic information is obtained for many new levels below 4.5 MeV excitation. Low-spin states are found to be a mixture of spherical-vibrational, two-particle, and intruder configurations. The emerging intruder band is identified in ^{120}Te. The situation in ^{122}Te and ^{124}Te is not quite as clear.

WINTERSGILL, M. C., Professor and FONTANELLA, J. J., Professor, "Electrical Conductivity, DSC and NMR Studies of PEG and PPG Containing Lithium Salts," *Solid State Ionics*, Vol 135, pp.155-161, 2000.

Complex impedance, differential scanning calorimetry (DSC) and 7Li nuclear magnetic resonance (NMR) studies have been carried out on poly(propylene glycol) (PPG) with an average molecular weight of 4000 and poly(ethylene glycol) mono-methyl-ether with an average molecular weight of 350 (PEG) containing lithium salts. The impedance studies were made over a range of frequencies, temperatures and pressures and were used to obtain values of electrical conductivity. The DSC, conductivity and NMR data are used to characterize the PPG-based material which is a glass-forming liquid. The PEG-based material exhibits the expected tendency to crystallize. The first new result is that the effect of pressure on the electrical conductivity (activation volume) for the PEG-based electrolyte above the melting point is about half that for the PPG-based electrolyte. The same trend has been reported previously for the pressure variation of the glass transition temperature for related host polymers. The second new result is that the curvature in the effect of pressure on the electrical conductivity is opposite for the two electrolytes. It is pointed out that the curvature for PPG:$LiCF_3SO_3$ has the same sign as the effect of pressure on the relaxation relaxation in PPG. These results provide further evidence that ionic conductivity is controlled by large scale segmental motions of the polymer chain. Further explanation of the data is given in terms of free volume.

Yates, S.W., Brown, T.B., Hannant, C.D., VANHOY, J.R., Professor, and Warr, N., "Using (n,xn³) Reactions to Probe Nuclear Structure," *Heavy Ion Physics*, 12, 295 (2001).

Building on nuclear spectroscopic methods developed with the (n,n') reaction, we have examined reactions with higher-energy neutrons to determine their utility for studying the structure of nuclei. Studies have been performed with spallation neutrons from the LANSCE/WNR facility and reaction channels with as many as 27 emitted neutrons have been observed. At the University of Kentucky accelerator laboratory, the ^{2}H(d,n) and ^{3}H(d,n) reactions have been used to produce neutrons with energies up to 22 MeV. Spectroscopic measurements at these lower energies, where the (n,2n³) and (n,3n³) reactions dominate, appear to have greater potential for yielding new spectroscopic information than those at higher energies.

Conference Proceedings

Hicks, S.F., VANHOY, J.R., Professor, Warr, N., Brown, T.B., and Yates, S.W., "Utilization of the (n,n'³) Reaction for Nuclear Structure Studies of ^{122,124,126}Te," *Proceedings of the Conference on Applications of Accelerators in Research and Industry 2000*, Edited by J. Duggan, Singapore: World Scientific, (2001).

The collective properties of levels to 3.3 MeV excitation in ^{122,124,126}Te have been investigated using the (n,n¢g) reaction. Measurements were made at the neutron scattering facilities at the University of Kentucky. Gamma-ray angular distributions, Doppler shifts, excitation functions, and g-g coincidences were measured. Level spins, parities, lifetimes, branching ratios, and multipole-mixing ratios have been deduced. The experimental methods used in this study and examples of nuclear structure questions in ^{122,124,126}Te that have been investigated are discussed.

HUDDLE, James R., Associate Professor, "PIXE and Moseley's Law," *Proceedings of the 16th Conference on the Applications of Accelerators in Research and Industry*, Denton, TX, 1-4 November 2000.

In an undergraduate atomic physics experiment, 2.8 MeV protons are used to bombard thick elemental targets. X rays emitted from the targets are detected with a Si(Li) detector, and their energies are measured with a multichannel analyser. The Ka and Kb x-ray energies are each plotted as functions of (Z-1)2, and the Rydberg energy, Rch, is extracted from the slopes of the resulting lines. The Ka plot gives Rch = 14.099 ± 0.025 eV, while the Kb plot gives 13.557 ± 0.027 eV. The experiment extends the Bohr Theory as discussed in class, serves to introduce PIXE as a quantitative technique for elemental analysis, gives the students experience in using modern instruments which may be used in later experiments, and experience in using uncertainty analysis to decide whether their measurements agree or disagree with other measurements or theoretical calculations. Although the experimental values differ from each other and from the accurately known value of 13.606 eV by less than 4%, they do <u>not</u> agree to within the experimental uncertainties, forcing students to consider a systematic error arising from their use of the Bohr Theory to derive Moseley's Law.

TANKERSLEY, L. L., Professor, Reintjes, J., Tucker, J.E., Schultz, A., Lu, C., Howard, P.L., Sebok, T., and Holloway C., "Lasernet Machinery Monitoring Technology," *Proceedings of the Symposium on Conditioned-Based Maintenance for Highly Engineered Systems*, Pisa, Italy, 25-27 September, 2000. (CD-ROM)

The analysis of debris present in machinery lubricating systems has the ability to provide fault-specific information in a timely manner to support diagnostics and prognosis of machinery maintenance. This capability allows the avoidance of catastrophic failures and enables improved cost-effective asset-management philosophies, especially in the area of timely maintenance and reduction of maintenance induced failures. Essential to achieving these asset management and condition based maintenance goals, are technologies that can provide reliable early identification of fault or failure mechanisms and the degree of degradation of the machine's performance capabil-

ity. These technologies must also assess the effect of the performance degradation with its impact on the machine's mission requirements, the system that it supports in a shipboard environment or the affected factory environment. The LaserNet Fines instrument delivers a technology which has significant potential in these areas. Using laser imaging techniques and advanced image processing software LaserNet Fines determines the type, severity and rate of progression of mechanical faults by measuring the size distributions, rate of production and the morphological analysis of debris particles in fluids. This instrument also has the capabilities of identifying contaminants, free water and fibers in a wide range of fluids such as mineral and synthetic lubricants and hydraulic fluids. This paper discusses these capabilities and features of the LaserNet Fines instrument along and with examples from both field and laboratory evaluations.

TANKERSLEY, L. L., Professor, Reintjes, J., Tucker, J.E., Schultz, A., Lu, C., Howard, P.L., Sebok, T., and Holloway, C., "Application of LaserNet Fines to Mechanical Wear and Hydraulic Monitoring," *Proceedings of HUMS 2001 – DSTO International Conference on Health and Usage Monitoring*, Melbourne, Australia, 19-20 February 2001.

We describe the application of LaserNet Fines to the detection of mechanical wear in diesel engines and hydraulic contamination in a variety of systems. The ability to relate LaserNet Fines results to specific types of faults and the use of LaserNet Fines results for root cause analysis and recommendation of remedial action is discussed.

TANYI, J.A., Midshipman 1/C, (USN) (presenter), CHURCHILL, T., Midshipman, 3/C, (USN), Crandell, K.A., VANHOY, J.R., Professor, Burns, M.C., Roddy, P.A., Hicks, S.F., Ammar, Z., Brown, T.B, Merrick, M., Warr, N., and Yates, S.W., "The Generalized Collective Model and its Application to the Even-Even Tellurium Nuclei," *Proceedings: Eleventh National Conference on Undergraduate Research 2001*, Edited by R.D. Yearout, Asheville: University of North Carolina at Asheville Press, (2001).

The excited levels of the stable even-even tellurium nuclei have been examined from the viewpoint of the Gneuss-Greiner formulation of the General Collective Model. The potential energy surfaces obtained are generally consistent with spherical vibrational nuclei but show a slight tendancy toward prolate deformation. Any deformation minima are shallow. Application of the Gneuss-Greiner form of the potential to the ground state, first excited state, quadrupole triplet, and several of the 3-phonon states did not reveal the deformed shape with gamma soft character reported using the Dynamic Deformation Model potential. It remains to be seen if that interpretation was the result of including particle-like states (specifically the 6^+, 8^+), which are known to lie outside the GCM model space.

VANHOY, J.R., Professor, Yates, S.W., Brown, T.B., Hannant, C.D., and Warr, N., "Using (n,xn^3) Reactions to Probe Nuclear Structure," *Proceedings of the International Symposium on Exotic Nuclear Structures*, Edited by Zs.Dombradi and A. Krasznahorkay, Hungary: Piremon, p.199. (2001).

Building on nuclear spectroscopic methods developed with the (n,n') reaction, we have examined reactions with higher-energy neutrons to determine their utility for studying the structure of nuclei. Studies have been performed with spallation neutrons from the LANSCE/WNR facility and reaction channels with as many as 27 emitted neutrons have been observed. At the University of Kentucky accelerator laboratory, the ^{2}H(d,n) and ^{3}H(d,n) reactions have been used to produce neutrons with energies up to 22 MeV. Spectroscopic measurements at these lower energies, where the (n,2n^3) and (n,3n^3) reactions dominate, appear to have greater potential for yielding new spectroscopic information than those at higher energies.

VANHOY, J.R., Professor, Hicks, S.F., Warr, N., Alexander, G.K., Aubin, C.A, Burkett, P.G., Burns, M.C., CHAMPINE, B.R., Midshipman 1/C, USN, B.R., COLEMAN, Midshipman 1/C, USN, R.T., Collard, C.J., Corminboeuf, F., Crandell, K.A., Etzkorn, S.J., Garrett, P.E., Genilloud, L., Jolie, J., Kern, J., Shenker, J.L., Sklaney, B.K., TANYI, J.A., Midshipman 1/C, USN, Walbrun, M.M., and Yeh, M.,"Coexisting Structures in the $^{120\text{-}124}$Te Nuclei," *Proceedings of the International Symposium on Exotic Nuclear Structures*, Edited by Zs. Dombradi and A. Krasznahorkay. Hungary: Piremon, 191. (2001).

The level schemes of the mid-shell tellurium nuclei, A=120-124, have been developed utilizing in-beam ^{3}-ray spectrosopy following the (n,n'^{3}) and (±,2n^{3}) reactions and Iodine beta decay. Excitation functions, ^{3}-^{3} coincidences, and angular distributions were measured. Spectroscopic information is obtained for many new levels below 4.5 MeV excitation. Low-spin states are found to be a mixture of spherical-vibrational, two-particle, and intruder configurations. The emerging intruder band is identified in ^{120}Te. The situation in ^{122}Te and ^{124}Te is not quite as clear.

VanLehn, K., Freedman, R., Jordan, P., Murray, C., Osan, R., Rignenberg, M., Rose, R., SCHULZE, K.G., Professor (Computer Science Department), SHELBY, R., Professor, TREACY, D., Professor, Weinstein, A., and WINTERSGILL, M.C., Professor, "Fading and Deepening: The Next Steps for ANDES and other Model-Tracing Tutors," *Proceedings of the 5th International Conference, ITS 2000*, Montreal Canada, Springer-Verlay, Berlin.

Model tracing tutors have been quite successful in teaching cognitive skills; however, they still are not as competent as expert human tutors. We propose two ways to improve model tracing tutors and in particular the Andes physics tutor. First, tutors should fade their scaffolding. Although most model tracing tutors have scaffolding that needs to be gradually removed (faded), Andes scaffolding is already (faded) and that causes student modeling difficulties that adversely impact its tutoring. A proposed solution to this problem is presented. Second, tutors should integrate the knowledge they currently teach with other important knowledge in the task domain in order to promote deeper learning. Several types of deep learning are discussed, and it is argued that natural language processing is necessary for encouraging such learning. A new project, Atlas, is developing natural language based enhancements to model tracing tutors that are intended to encourage deeper learning.

Technical Reports, Books and Book Chapters

EDMONDSON, C. A., Associate Professor and FONTANELLA J. J., Professor, "Complex Impedance Studies of S-SEBS Block Polymer Proton-Conducting Membranes," Office of Naval Research, Technical Report # 23, 1 July 2000.

Water uptake, swelling, ^{1}H pulsed gradient spin-echo nuclear magnetic resonance (NMR) and variable temperature and pressure complex impedance/electrical conductivity studies have been carried out on sulfonated styrene /ethylene-butylene /styrene (S-SEBS) triblock polymer proton conducting membrane. All of the data show different characteristics above and below about 10 wt-% water. For example, the diffusion coefficients, D from NMR and $D_{s\delta}$ calculated from conductivity data (which are the same to within experimental uncertainty), show different dependence on water above and below about 10 wt-% At high water content, the properties of S-SEBS are similar to those for Nafion 117, proton transport being similar to that in bulk water. For low water contents, however, the materials are different. For low water content S-SEBS, the variation of the conductivity with temperature is Arrhenius while that for Nafion 117 is not. The variation of the electrical conductivity with pressure gives rise to activation volumes on the order of 14 cm3/mol while those for Nafion 117 are about four times larger. These results indicate that proton transport in low water content S-SEBS occurs via a thermally activated process (ion motion via energy barriers), which is consistent with the rigid side chains in that material.

EDMONDSON, C. A., Associate Professor and FONTANELLA, J. J., Professor, "Percolation in S-SEBS and Fluorocarbon Proton Conducting Membranes," Office of Naval Research, Technical Report # 25, 1 July 2000.

Electrical conductivity results at a variety of pressures, temperatures and water contents are evaluated for sulfonated styrene/ethylene-butylene/styrene (S-SEBS) triblock polymer, Nafion 117, and Dow 800 proton conducting membranes. In addition, room temperature and atmospheric pressure diffusion coefficients determined from conductivity and ^1H pulsed gradient spin-echo nuclear magnetic resonance (NMR) studies are considered. While the S-SEBS and fluorocarbons exhibit a percolation threshold at 10 and 4 wt-%, respectively, all materials exhibit this phenomenon at a volume water fraction of C»0.035. Above the threshold the conductivity exhibits a power law behavior. When the volume of the hydrophobic portion of the membrane is subtracted the threshold occurs at the adjusted volume fraction of C_A»0.12 which approaches that expected for continuum percolation.

FONTANELLA, J. J., Professor, BENDLER, J. T., Associate Professor, and WINTERSGILL, M. C., Professor, "Effect of High Pressure on the Electrical Conductivity of Ion Conducting Polymers," Office of Naval Research, Technical Report # 22, 1 July 2000.

Complex impedance and differential scanning calorimetry (DSC) studies have been carried out on poly(propylene glycol) (PPG) with an average molecular weight of 1025 and poly(ethylene glycol mono-methyl-ether) (PEG) with an average molecular weight of 350, both containing $NaCF_3SO_3$ in an approximately 20:1 ratio of polymer to salt. The impedance studies were carried out over a range of frequencies, temperatures and pressures. As expected, PEG:$NaCF_3SO_3$ exhibits the tendency to crystallize while PPG:$NaCF_3SO_3$ is a glass-forming liquid. The fit to the zero pressure data for PPG:$NaCF_3SO_3$ using a recently developed generalized Vogel equation is better than that for the standard VTF equation while for PEG:$NaCF_3SO_3$ the two expressions give about the same level of fit to the data. In the theory, the critical temperature, T_c, is allowed to vary with pressure. The defect-defect separation is assumed to follow the dimensions of the material. It is found empirically that the pressure dependence of T_c is similar to the pressure dependence of T_g for structurally related polymers containing no salt. Thus, the difference in the pressure dependence of the conductivity for PEG:$NaCF_3SO_3$ and PPG:$NaCF_3SO_3$ is attributed primarily to the difference in the pressure dependence of T_g. The details of the relationship between T_c and T_g remain to be determined.

FONTANELLA, J. J., Professor, "Pressure and Temperature Variation of the Electrical Conductivity of Poly(propylene glycol) Containing $LiCF_3SO_3$," Office of Naval Research, Technical Report # 24, 1 July 2000.

Complex impedance and differential scanning calorimetry (DSC) studies have been carried out on poly(propylene glycol) with average molecular weight 1025 (PPG) and PPG containing $LiCF_3SO_3$. The impedance studies were made at frequencies from about 1 mHz to 100 MHz at pressures up to 0.3 GPa (3 kbar) over the temperature range 215-365 K. Both the impedance and DSC studies were carried out in vacuum or at atmospheric pressure over a temperature range of about 100-375 K. As a consequence, the impedance studies overlap the DSC glass transition temperature. The inadequacy of the widely used Vogel-Tammann-Fulcher or Williams-Landel-Ferry equations to describe the temperature variation of the vacuum electrical conductivity data is discussed. It is shown that the Bendler-Shlesinger formalism is a better representation of the data, particularly in the region close to the glass transition. The first pressure derivative of the electrical conductivity, and hence apparent activation volume, decreases strongly as temperature increases. In addition, the activation volumes are larger for the low molecular weight liquids that the values reported previously for related, high molecular weight rubbery electrolytes. Next there appears to be an exponential relationship between activation volume and the electrical conductivity. Finally, the pressure variation of the electrical conductance exhibits negative curvature which shows that the activation volume increases as pressure increases. A qualitative explanation of each of these results concerning the relationship between conductivity, temperature, and pressure is given in terms of free volume. However, whether free volume can provide a quantitative explanation remains to be determined.

HUDDLE, James R., Associate Professor, Solar Eclipse Newsletter Vol. 5, No. 8, p.11 (August 2000). http://sunearth.gsfc.nasa.gov/eclipse/SENL/SENL0008.pdf

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Trident Scholar Report

BRERETON, Peter G., Midshipman 1/C, USN, "Complex Impedance Studies of Optically Excited Strontium Barium Niobate," *U.S. Naval Academy Trident Scholar Report*, Number 279, (2001).

The complex permittivity and impedance of undoped and unpoled single crystal strontium barium niobate (SBN) were measured with a computer interfaced impedance analyzer over a frequency range from 100 millihertz to 10 kilohertz using small AC signals with millivolt amplitudes. The thin (~2 mm) planar crystal sample was placed between the plates of a modified parallel plate capacitor and illuminated on the side with linearly polarized argon-ion laser light operating at select wavelengths in the blue-green with photon energies that are slightly below the bandgap energy of SBN. Impedance spectra were obtained in the dark between room temperature and 70°C and compared with impedance spectra obtained with laser illumination and no heating except that produced by absorption of the laser light. Dark measurements at all temperatures are consistent with studies in the literature that suggest electron hopping as the predominant charge transfer mechanism. Illumination markedly changed the conductivity of the crystal and the charge transfer mechanism by elevating significant numbers of charge carriers into the conduction band. This was found to be independent of the polarization of the light and slightly dependent on its wavelength over our wavelength range of 458 nm to 515 nm. The dielectric constant of the crystal under illumination changed less than twenty per cent and is probably due to the slight heating of the crystal induced by the laser.

Presentations

CAMPBELL, Douglas T., Midshipman 1/C, USN and KATZ(-STONE), Debora M., Associate Professor, "Tracking Near-Earth Asteroids: A Trident Scholar Project," American Astronomical Society, Rochester, NY 4-8 June 2000.

EDMONDSON, Charles A., Associate Professor, WINTERSGILL, Mary C., Professor, and FONTANELLA, John J., Professor, "Electrical Conductivity of Proton Conducting Membranes," Seventh International Symposium on Polymer Electrolytes, Noosa, Australia, 6-11 August 2000.

ERTEL, John P., Associate Professor, "DC05: Modeling of Physics Systems Distributed Across Applications – the Next Step," Summer Meeting of the American Association of Physics Teachers, University of Guelph, Ontario, Canada, 1 August 2000.

ERTEL, John P., Associate Professor, Schwarz, Cindy, and Burt, Patricia E., "W21: Introduction to Interactive Physics III and Its Use in the Undergraduate Classroom/Laboratory," Winter Meeting of the American Association of Physics Teachers, at San Diego, CA, 7 January 2001. (invited half-day workshop)

ERTEL, John P., Associate Professor, Schwarz, Cindy, and Burt, Patricia E., "W30: Intermediate/Advanced Interactive Physics III and Its Use in the Undergraduate Classroom/Laboratory," Winter Meeting of the American Association of Physics Teachers, at San Diego, CA, 7 January 2001. (invited half-day workshop)

FONTANELLA, J. J., Professor, BENDLER, J. T., Associate Professor, Shlesinger, M. F., and WINTERSGILL, M. C., Professor, "Effect of High Pressure on the Electrical Conductivity of Ion Conducting Polymers," Seventh International Symposium on Polymer Electrolytes, Noosa, Australia.

FONTANELLA, J. J., Professor, EDMONDSON, C. A., Associate Professor, and WINTERSGILL, M. C., Professor, "Properties of Fuel Cell and Battery Materials," Air Force Office of Scientific Research and Office of Naval Research (AFOSR/ONR) Electrochemistry Review, Annapolis, MD, 2001.

HUDDLE, JAMES R., Associate Professor, "PIXE and Moseley's Law," 16th Conference on the Applications of Accelerators in Research and Industry, Denton, TX, 1-4 November 2000.

KATZ(-STONE), Debora M., Associate Professor and CAMPBELL, Douglas T., Midshipman 1/C, USN, "The Trident Scholar Program: Year-Long Undergraduate Research Projects at the United States Naval Academy," American Astronomical Society, Rochester, NY 4-8 June 2000.

KORMAN, M. S., Professor, "Scattering of Sound by Sound in the Presence of Turbulence: Doppler and Spectral Broadening Effects Using Pulses," National Center for Physical Acoustics (University of Mississippi, University, MS), 12 January 2001. (invited seminar)

KORMAN, M. S., Professor, "Demonstrations in Physics**,** Acoustics, Chaos, and Nonlinear Phenomenon: The Teaching Life of a Naval Academy Professor Involves an Intimate Exchange between the Midshipman and the Instructor," Naval Academy Preparatory School (NAPS), Newport, RI, 13 July 2001.

KORMAN, M. S., Professor, "Nonlinear Scattering of Crossed Ultrasonic Pulsed Beams in the Presence of Turbulence: Doppler Shift and Spectral Broadening Effects," 140th Meeting of the Acoustical Society of America, Newport Beach, CA, 3-8 December 2000.

KORMAN, M. S., Professor, "Hands on Demos in Chaos and Nonlinear Phenomenon for all Ages," Education in Acoustics: Hands on Demos for High School Students Session of the 141st Meeting of the Acoustical Society of America, Chicago, IL 4-8 June 2001.

KORMAN, M. S., Professor, "Nonlinear Scattering of Crossed Ultrasonic Beams in the Presence of Turbulence: Experiments Performed with Continuous Waves," (with Marlene Roush), Undergraduate Student Research Poster Session of the 141st Meeting of the Acoustical Society of America, Chicago, IL 4-8 June 2001.

MANRY, Rebecca A., Midshipman 1/C, (USN) and KORMAN, M. S., Professor, "Nonlinear Scattering of Crossed Ultrasonic Beams in the Presence of Turbulence: Experiments Performed with Pulses," Undergraduate Student Research Poster Session of the 141st Meeting of the Acoustical Society of America, Chicago, IL 4-8 June 2001.

MOSCA, Eugene P., Professor and ERTEL, John P., Associate Professor, "Axial Vectors: a Corridor Display (Demonstration of Left/Right-Handed Invariance)," Contributed to the Apparatus Competition at the Summer Meeting of the American Association of Physics Teachers, University of Guelph, Ontario, Canada, 1 August 2000.

MUNGAN, C.E., Assistant Professor, Bowman, S.R., and Gosnell, T.R., "Advances in Solid-State Laser Cooling," International Conference on Lasers 2000, Albuquerque, NM, 4–8 December 2000.

NOVO-GRADAC, A-M., Assistant Professor, Laux, A. E., and Narducci, F. A., 16th Interdisciplinary Laser Science, 22-26 October 2000.

SCHNEIDER, Carl S., Professor, "Domain Cooperation in Ferromagnetic Hysteresis," Physics Department, University of Delaware, Newark, Delaware, 13 April 2001.

SCHNEIDER, Carl S., Professor, "Domain Cooperation in Ferromagnetic Hysteresis," Office of Naval Research Meeting on Transduction Materials and Devices, Baltimore, MD, 14-16 May 2001.

Schwarz, Cindy and ERTEL, John P., Associate Professor, "W22: Using Computer-Based Technology in Teaching Physics," Summer Meeting of the American Association of Physics Teachers, at University of Guelph, Guelph, Ontario, Canada, 30 July 2000. (invited full-day workshop)

SHELBY, Robert N., Professor, TREACY, Donald J., Professor, SCHULZE, Kay G., Professor, and WINTERSGILL, Mary C., Professor, "Andes: A Tutoring System for Classical Physics," American Association of Physics Teachers Summer Meeting, Guelph, Canada, 29 July - 2 August 2000.

TANKERSLEY, L.L., Professor, Reintjes, J., Tucker, J.E., Schultz, A., Willey, Jefferson, O'Brien, Amy, Howard, Paul, Lu, Chao, and Thomas, Scott, "Lasernet FINES," Naval Research Laboratory, Washington, DC, and Pisa, Italy, 25-27 September 2000.

VANHOY, J.R., Professor, TANYI, J.A., Midshipman 1/C, USN, CHURCHILL, T., Midshipman 3/C, USN, Crandell, K.A., Burns, M.C., Roddy, P.A., Hicks, S.F., Ammar, Z., Brown, T.B., Merrick, M, Warr, N., and Yates, S.W., "The General Collective Model and its Application to Even-Even Tellurium Nuclei," American Physical Society Meeting, Washington, DC, 28 April –1 May 2001.

VANHOY, J.R., Professor, "Fun with NATALY," Gettysburg College, Gettysburg, PA, 09 November 2000.

VANHOY, J.R., Professor, TANYI, J.A., Midshipman 1/C, (USN) (presenter), CHURCHILL, T., Midshipman, 3/C, (USN), Crandell, K.A., Burns, M.C., Roddy, P.A., Hicks, S.F., Ammar, Z., Brown, T.B., Merrick, M., Warr, N, and Yates, S.W., "Generalized Collective Model Description of ^{126}Te Excited States," National Conference on Undergraduate Research NCUR2001, Lexington, KY, 15-17 March 2001.

VANHOY, J.R., Professor, HUDDLE, J.H., Associate Professor, CORRELL, F.D., Professor, and MOORE, D.M., Laboratory Support Staff, "Educational Activities Using The USNA Pelletron 5SDH-1," Conference on the Applications of Accelerators in Research and Industry, Denton, TX, 01-04 November 2000. (invited presentation)

VANHOY, J.R., Professor, Hicks, S.F., Warr, N., Brown, T.B., and Yates, S.W., "Nuclear Structure of Low-Lying Collective States in ^{122,124,126}Te," Conference on Applications of Accelerators in Research and Industry, Denton, TX, 01-04 November 2000.

VANHOY, J.R., Professor, TANYI, J.A., Midshipman 1/C, (USN), CHURCHILL, T., Midshipman 3/C, (USN), Crandell, K.A., Burns, M.C., Roddy, P.A., Hicks, S.F., Ammar, Z., Brown, T.B., Merrick, M., Warr, N., and Yates, S.W., "Competing Structures in ^{126}Te," Division of Nuclear Physics of the APS Meeting, Williamsburg, VA, 03-07 October 2000.

ZIEGLER, J. F., Visiting Professor, "The Stopping and Range of Ions in Matter," International Ion Implantation Conference, Austria, September 2000. (invited plenary talk)

ZIEGLER, J. F., Visiting Professor, "The History of Soft Fail Reliability in the Computer Industry," NASA Workshop on Electronic Reliability, Stanford University, October 2000. (invited plenary talk)

ZIEGLER, J. F., Visiting Professor, "The Impact of Soft Fails on Computer Reliability," Sundstrand Control Division of United Technologies, Hartford, CT, November 2000. (invited talk)

ZIEGLER, J. F., Visiting Professor, "The Effects of Thermal Neutrons on Electronics," International Business Machines (IBM) Research, Yorktown, NY, March 2001.

ZIEGLER, J. F., Visiting Professor, "The Probability of Soft Fails in SRAM and DRAM Technologies," Sun Microsystems, Cupertino, CA, October 2001.