Astronomy, Mathematics, and Physics

IN SITU CHARACTERIZATION OF POLYMER AND DYE pH SENSING FILMS. D. M. Topasna, T. A. Emig, S. A. Cox, & G. A. Topasna, Department of Physics and Astronomy, Virginia Military Institute, Lexington, VA 24450. We describe the steps in creating the experimental set-up for in situ characterization of thin films made by ionic self-assembled monolayers technique. The films are fabricated by alternate immersion of transparent substrates in aqueous solutions of poly(allylamine hydrochloride) and Direct Yellow 4. The absorbance of films changes when the pH of the surrounding medium changes. These types of films have potential applications in the biomedical field and as optical pH sensors. The transparent films were immersed in solutions at various pH values and their absorbance was monitored. Long time (48 hours) measurements of absorbance also indicate photobleaching of the films.

THE SPECTRAL FUNCTION OF ^{40}Ar THROUGH THE (e,e'p) REACTION. Donal Day, Department of Physics, University of Virginia, Charlottesville, VA 22904. Accelerator based neutrino-oscillation measurements, where neutrinos interact predominantly with nucleons bound in nuclei, demand an accurate description of the cross sections. Nuclear effects play a decisive role and are considered one of the main sources of systematic uncertainties. An effort is underway to develop theoretical models capable of a fully quantitative description of the neutrino-nucleus cross sections. An approach based on many body theory has proven successful in explaining electron-nucleus cross sections. The application of this approach to the analysis of neutrino interactions will require accurate models of the spectral functions for the nuclei in neutrino detectors. Of paramount importance is ^{40}Ar, to be used in the Deep Underground Neutrino Experiment (DUNE, formerly LBNE). A ^{40}Ar(e,e'p) experiment which will prove indispensable for the construction of the argon spectral function has been approved at Jefferson Lab. The (e,e'p) data, in addition, will advance theoretical developments, including the description of final-state interactions, unavoidable in neutrino experiments. The motivation, goals, experimental details and plans for the execution of this measurement will be discussed.

PHYSICAL MODELS OF TOROIDAL DIPOLE MOMENT (ANAPOLE). Amanuel Eshete, Armian Hanelli, Paige Andros, Denny Okudinani & Walerian Majewski, Dept. of Physics and SPS Chapter, Northern Virginia Community College, Annandale, VA 22003. We are

investigating two models of the third elementary dipole, known as the toroidal dipole moment (anapole). The magnetic model is a circumferentially and uniformly magnetized ring constructed of neodymium magnets. The electric model is a toroidal coil connected to a DC or AC voltage. DC-current electric and ideal magnetic toroids produce only an inner magnetic field, and interact directly with a curl of the external magnetic field, that is, in effect, with a conductive current density or with a displacement current. We studied the characteristics of permanent-magnet and electric toroids, and measured the effects of a curl of the external magnetic field (produced by linear current) or a time-dependent displacement current on the toroid. An effective toroidal dipole moment of the magnetic toroid was measured in interaction with the external current and compared with the calculated theoretical value. Rotating the magnetic toroid or passing an alternate current in the windings of electric toroid should make them act as electric dipole antennas and produce electric dipole quasi-static fields and radiation. These fields and radiations move as a wave, radially from the outer edge of the toroid. We are attempting to detect and measure these near-zone electromagnetic fields, as well as an integrated value of the external magnetic vector potential. A toroid's magnetic field should be also penetrating outside of the toroid if it is placed in an electromagnetic medium instead of a vacuum.

COSMIC RAY MUONS IN THE STANDARD MODEL OF FUNDAMENTAL PARTICLES. Hannah Glaser, Roberto Rivas, Angel Gutarra-Leon, Cioli Barazandeh & Walerian Majewski, Department of Physics and SPS Chapter, Northern Virginia Community College, Annandale, VA. Muons are one of the twelve fundamental particle types of matter, having the longest free-particle lifetime. It decays into three other leptons through an exchange of the weak vector bosons W^+/ W^-. Muons are present in the secondary cosmic ray showers in the atmosphere, and reach the sea level. Cosmic rays are a natural "poor man's accelerator" for community colleges. By detecting the delay time between arrival of the muon and an appearance of the decay electron in our single scintillation detector, we measured the muon's lifetime at rest in the material of our detector. After correcting it by the known ratio of positive and negative muons in the flux and taking into account the known rate of the negative muon capture in the material, we were able to extract from our data the lifetime of the free positive muon, identical to the lifetime of both muons in vacuum. It compares well with the established value. Using literature data on muon fluxes at different heights in the atmosphere, we estimated the relativistic time dilation of muons. From our lifetime measurement we were able to

calculate the ratio of g_w /M_W for the weak coupling constant g_w to the mass of the W-boson M_W. Using further Standard Model relations and an experimental value for M_W, we calculated the weak coupling constant, the electric charge of the muon, and the vacuum expectation value of the Higgs field. We also measured the sea-level flux of low-energy (below 160 MeV) muons, which are slow enough to be stopped in our detector. We also found the shapes of the energy spectra of low-energy muons and of their decay electrons. We have not found a systematic difference between day and night muon fluxes.

A COMPARISON OF ELECTROMAGNTIC LEVITATION WITH AN ELECTRODYNAMIC WHEEL ON DIFFERENT METAL CONDUCTORS. Angel J. Gutarra-Leon, Vincent Cordrey & Walerian Majewski, Department of Physics, Northern Virginia Community College, Annandale VA 22003. We built a high-density, externally driven magnetic wheel and tested a lift/drag formula derived initially for linear motions of magnets with respect to inductive tracks. We maximized the levitation efficiency by using Halbach array of dipole magnets, with the peak magnetic field strength of 0.4 Tesla and a working field of 0.18 Tesla at the measuring distance. Experiments were performed on a total of five different conductive plates or "tracks". We verified applicability of the theoretical lift/drag formula to this rotational system. The lift-off speeds were reached. We also developed a program to convert raw oscillatory data into the averaged force graphs. We are currently in the process of improving the stability of the system in order to get better measurements at higher to allow measurements at higher angular velocities. (Supported by: the Society of Physics Students and the Virginia Academy of Sciences)

EFFECT OF ANGLE DEPENDENCE ON THE ELECTRIC AND ENTROPIC CONTRIBUTIONS OF INFRARED POWER GENERATION. Justin M. Kaczmar[1], Brian C. Utter[2], Giovanna Scarel[1], [1]Dept. of Physics and Astronomy, James Madison University, Harrisonburg VA 22802 and [2]Dept. of Physics and Astronomy, Bucknell University, Lewisburg PA 17837. In studying alternative methods for energy harvesting we use a power generator device to produce a voltage by striking it with infrared radiation. What we have been investigating is the effect of changing the angle at which we strike the device with in relation to the produced voltage. We observe an overall voltage rise with relation to the angle and attribute this to two components: an electric and entropic contribution in the time immediately after turning the infrared radiation on. By taking the total voltage by the two components and plotting it as a function of the angle at which they were taken at, we find a distinct effect on the total

voltage measured when performed at certain angles versus others. We specifically find that the electric contribution to the total sum becomes more pronounced as the angle increases while the entropic becomes less so.

EFFECT OF TRANSFORMATION TEMPERATURE ON NANO PARTICULATE SIZE. William B. Lambert & Rama Balasubramanian, Dept. of Mathematics, Computer Science, and Physics, Roanoke College, Salem VA 24153. Nanoparticles are structures ranging from 10 to 100 nanometers that can be used for a variety of applications spanning from nanotube substrates to smart coatings. Nanoparticles of hematite (α-Fe_2O_3) and maghemite (g-Fe_2O_3), used in magnetic storage media and as contrast agents in MRI, can be produced in a variety of ways such as weathering, sol-gel synthesis, and through solid state transformation. This study explores the properties of nanophase hematite formed from solid-state transformation of maghemite. In order to understand the dependence of particle size on transformation temperature, seven samples of hematite were synthesized from maghemite at temperatures ranging from 175-700°C. The hematite samples were characterized using X-Ray diffraction and the mean crystalline diameter (MCD) was calculated using Scherrer equation. As the transformation temperature increased from 175-325°C, XRD measurements showed the presence of both maghemite and hematite phases. The MCD of the samples ranged from approximately 9 nm to 16 nm. As the transformation temperature increased form 400-700°C, the samples were completely transformed to hematite and the MCD increased from approximately 18 nm to 78 nm. Between 175-325°C the particle size showed a linear dependence on transformation temperature. However, as the transformation temperature increased from 400-700°C the particle size followed a 2nd degree polynomial dependence. The transformation at lower temperatures is said to be topotactic while aggregation of hematite crystals was rapid at higher transformation temperatures. Detailed results from the study will be presented.

DEVELOPMENT AND VERIFICATION OF A NEW POST ROLL-UP MODEL FOR CHARACTERIZATION OF AIRCRAFT LIFT GENERATED WAKE VORTICES. Steven H. Lohrey, Dept. of Physics, Randolph-Macon College, Ashland VA. 23005. This presentation documents research findings for four post roll-up two-dimensional flow-field models for a counter-rotating pair of vortices generated by aircraft lift. The governing equations that define the velocity distributions for the four models considered are all derived from an identical physics based theoretical formulation. Vector potential methods were employed to derive the governing velocity

equations for each of the four models. Of the four models studied, three are well known in the literature and are currently used in a variety of wake turbulence applications; albeit they were not derived from vector field potentials. The fourth flow model is a new result that was developed during this research project. Basic parameters for each vortex model, such as peak tangential (Swirl) velocity, and circulation strength as a function of vortex core size, were examined. The new model was validated using data acquired in a NASA wind tunnel experiment using a 3% scale model of a Boeing 747 as the generator for the counter-rotating vortex pair flow field. Vortex induced forces and moment data were measured for three different well instrumented down-stream wing configurations immersed in the B747 wake flow field. The comparison between the calculated and measured vertical velocities showed very good results for the new Lohrey-Bowles model. The induced lift force coefficient and the induced rolling moment coefficient for the three different wing configurations were also calculated for this model and showed excellent agreement with the wind tunnel measurements.

WHAT IS DATA SCIENCE? David J. Marchette, Naval Surface Warfare Center, Dahlgren, VA, 22448. Data science, data analytics, big data: these terms are thrown around frequently these days. But what exactly is "Data Science"? In this talk I will try to answer this question by looking at the term through several lenses: as a process for data analysis; in relation to well-known disciplines such as statistics and computer science; a set of tools; and finally as it relates to science. I will give a very high-level view of the field, touching on these issues from various perspectives. I will discuss a few of the algorithms and tools that are used in the field (from a very idiosyncratic perspective) and talk very briefly about some applications.

STEM TAKES FLIGHT. Thomas C. Mosca III, Rappahannock Community College, Department of Mathematics, Warsaw, VA 22572. The Virginia Space Grant Consortium (VSGC) in partnership with the Virginia Community College System (VCCS), NASA Langley Research Center and NASA Wallops Flight Facility is offering the STEM Takes Flight initiative for Virginia's Community Colleges. STEM Takes Flight provides a suite of programs for Virginia community college students pursuing STEM majors and faculty in STEM disciplines statewide. Opportunities include $5,000 mentored scholarships, paid onsite research experiences at NASA Langley and NASA Wallops, paid industry internships, new courses and a NASA

residential faculty professional development workshop. This year I participated in the faculty workshop, and the Antares ISS resupply mission simulation based on the Orbital ATK Cygnus Mission #2 launch. This presentation highlights the experience with hopes of encouraging participation in future opportunities.

LASER MATTER INTERACTION. Hai T. Nguyen, Department of Physics, University of Mary Washington, 1301 College Avenue, Fredericksburg, VA 22401. Single frequency lasers in conjunction with miniature Acousto-Optic Modulators (AOM) enables new kind of phase modulators for various experiments. We cool and trap Rubidium atoms to measure energy-dependent charge exchange cross sections in the Cs^+ + Rb(5s, 5p) system over a range of projectile energies. Also, we use AOM diffractions in interference experiments between two beams of light, in a Mach Zehnder interferometer. The frequency differences of the many different optical orders of diffraction are well known and are easily controlled *via* the AOM electronic circuits and phase modulation. We use it to study heterodyne detection which allows for high efficiency coherent optical memory with warm rubidium vapor experiments suitable for quantum information applications, therefore, reducing the need for complicated trapping and cooling. We developed this optical heterodyne detection technique for various applications including optical memory delay, storage and readout. Furthermore, the ability to manipulate, enhance, and control of up-conversion multicolor output of UCNPs is particularly important for their applications in multiplexed biological applications. The output brightness of upconverting nanoparticles has been limited by questions about energy transfer and relaxation within individual nanocrystals and unavoidable tradeoffs between brightness and size. The common denominator in these questions is the upconverting efficiency of each individual UCNPs. The aim is to increase our knowledge and ability to manipulate, enhance, and control of single UCNP NaYF4 co-doped with Yb3+/Er3+ upconverting efficiency by trapping and exciting the single UCNP with one single laser at 915 nm.

A ROTATING METRIC THAT INCLUDES THE ENERGY DENSITY OF THE GRAVITATIONAL FIELD. Joseph D. Rudmin, Dept. of Integrated Science and Technology, James Madison University, Harrisonburg, VA, 22807. Several problems or concerns in general relativity are discussed regarding the use of an isotropic metric: Energy density of the fields, conformal flatness, rank-1 tensor derivatives for a rank-2 tensor field, reason and application of the equivalence principle,

and preservation of quantum unitarity. It is shown that conservation of energy with an isotropic metric yields a self-consistent model of general relativity and quantum mechanics. Since this talk is an instructional review rather than a presentation of results, publication of this abstract in the Virginia Journal of Science is not expected. The audience should be familiar with Maxwell's Equations and vector transformations.

POLARIZATION OF THE OPEN CLUSTER NGC 7380. G. A. Topasna, Dept. of Physics and Astronomy, Virginia Military Institute, Lexington, VA 24450. Polarization measurements were made of the open cluster NGC 7380 using the optical polarimeter on the 0.5 m telescope at the VMI observatory. The analysis shows that the ratio of total to selective extinction for the area centered on the cluster is 3.05 ± 0.09. A strong correlation exists between the wavelength of maximum polarization and the color index (B – V) and a linear correlation between the wavelength of maximum polarization and color excess but with outliers suggesting further study of these stars. The visual extinction is found to be 1.7 ± 0.1 magnitudes and the cluster distance was determined to be 2.5 ± 0.4 kpc.

EXCITATION AND DETECTION OF UPCONVERTING NANOPARTICLES. Pengcheng Zhang, Dept. of Physics, University of Mary Washington, Fredericksburg VA 22401. The up-conversion of nanoparticles has many applications in the fields of Biology and medical research, such as single molecule spectroscopy, colloidal dynamics, protein isolation, and controlled investigation of biological processes. In particular, it provides an alternative method for cancer treatment delivery. The advantages of using nanoparticles include higher sensitivity and the occurrence of quantum effects at the nano-scale. The up-conversion of nanoparticles has been experimented and well-studied with 980 nm lasers. However, due to its high water absorption, the 980 nm laser is not ideal for medical and surgical applications. Alternatively, many ongoing researches study the effectiveness of 915 nm lasers, or other lasers with relatively low water absorption. Particularly, we will look at an ongoing experiment at the University of Mary Washington Physics Department studying the excitation and detection of up-converting nanoparticle using both 915 nm and 980 nm lasers.