2024 Meeting of the TAAPT

Middle Tennessee State University

Friday, March 29 and Saturday, March 30

Schedule At A Glance

Friday, March 29 – Science Building, 2nd floor Atrium

- 5:30 pm to 6:00 pm – Check-in and registration
- 6:00 pm to 7:00 pm – Dinner
- 7:00 pm to 8:00 pm – Keynote Speaker, Dr. Hanna Terletska, "The Exciting World of Quantum Science"

Saturday, March 30 – Science Building, room 1006

- 8:00 am to 8:55 am – Registration/ light breakfast (pastries, tea, coffee)/poster setup
- 8:55 am to 9:00 am – Welcoming Remarks (Dr. Ron Henderson, Chair, Department of Physics and Astronomy)
- 9:00 am to 10:30 am – Oral presentations
- 10:30 am to 10:45 am – break/poster setup
- 10:45 am to 11:15 pm – Business meeting/poster setup
- 11:15 pm to 12:00 pm – poster session
- 12:00 pm to 12:10 pm – poster prizes
- 12:10 pm to 1:00 pm – lunch
- 1:00 pm to 2:30 pm – Quantum Science Workshop

Program for Saturday, March 30 – Science Building, Room 1006

8:00 – 8:55 **Registration/light breakfast (first floor atrium, outside room 1006)**

8:55 – 9:00 **Welcome Remarks, Dr Ron Henderson**

9:00 – 9:15 **Geoffrey Burks, Tennessee State University**
What Happens When the Wind Doesn't Blow and the Rain Doesn't Shine? A New Text Book for Physical Science

I am updating the two semester physical science class at UT-Southern. Recently we have been asked to design an updated "Concepts in Physical Sciences" class at TSU. Both classes need to be able to meet the Earth and Space Sciences needs of elementary school teachers. The present books are getting old and are somewhat disjointed. In order to increase student knowledge retention and engagement, I am working on a textbook that has a though story line. The Story is centered on the questions: How is electricity generated? And what is all the interest in renewable energy about? The text ultimately focuses on topics that school teachers and all students will have to deal with as they live in the 21st century. The book focuses on the physical science that is used in the 5 parts of the UT curriculum for the 2 semester course: Physics, Chemistry, Astronomy, Atmospheric Science, and Geology. Parts of the text are used for the 1 semester version.

9:15 – 9:30 **Chuck Higgins, Middle Tennessee State University**
The 2024 Solar Eclipse

Are you ready for another solar eclipse? If so, get ready for April 8, 2024. This time the path of totality does not fall over Murfreesboro, so you will have to travel to a nearby state like Arkansas, Missouri, Illinois, Indiana, or Ohio to see a total eclipse. If you plan to stay here, you will experience a 93% partial eclipse and see a dimmed sky in the middle of the day, a bit like twilight. Because the Sun is not completely covered, you will need to use solar eclipse glasses to view the Sun. I will discuss solar eclipses and highlight the upcoming 2024 solar eclipse.

9:30 – 9:45 **Cahit Erkal, University of Tennessee at Martin**
Autonomous Driving a Wheeled Robot, The Claw

An autonomous driving project called the CLAW will be presented. The purpose of this project was to train students who are in engineering and in computer sciences on autonomously driving robots. The result of the course is to build a small-sized autonomous vehicle that navigates the corridors by avoiding obstacles. This talk will describe an extended version of such a project. A meter-size robot was built as a test platform to investigate the most effective teaching strategies, but also with a view to future collaborations involving more students and other faculty. A previous collaboration resulted in a publication led by several UTM engineering students as their senior project under the supervision of an engineering faculty.

9:45 – 10:00 Jason Alexander, University of Tennessee at Martin
A pilot course in quantum information science and technology (QIST) at the University of Tennessee at Martin

We will discuss the successes and challenges to date in our first semester offering a hands-on introduction to QIST in the Department of Chemistry and Physics at UT Martin. The course is designed for students with only a background in college algebra to gain experience through a series of laboratory exercises and lecture/online modules. Each module lasts approximately 1-2 weeks. Modules are chosen to align with skills and experiences identified in the QIST Workforce Development National Strategic Plan, www.quantum.gov/wp-content/uploads/2022/02/QIST-Natl-Workforce-Plan.pdf

10:00 – 10:15 Bill Robertson, Middle Tennessee State University
Acoustic Impulse Response for Undergraduate Research and Advanced Lab Experiments
An experimental platform for audio-frequency acoustic impulse response measurements is described. By using the coherent averaging technique, the system is capable of high signal-to-noise measurements with a computer-based data acquisition system, amplifier, speaker, and microphone. When coupled to simple acoustic waveguide test systems fabricated from commercial PVC plumbing pipe, impulse response has proven to be an effective source of undergraduate or science fair research projects—many of publishable quality—or for advanced laboratory experiments.

10:15 – 10:30 **Tatiana Allen and Matthew Boone, University of Tennessee at Chattanooga**
A LEGO Kibble Watt Balance

In 2019, the International System of Units' unit of mass, the kilogram, was redefined based on the fixed value of the fundamental Planck's constant, therefore eliminating the need for the International Prototype of Kilogram, the platinum-iridium cylinder that was forged in 1879. The apparatus that allows to realize the kilogram based on the Planck's constant has been constructed at the National Institute of Standards and Technology (NIST). It is based on the idea of Bryan Kibble to balance the weight of the object by the electromagnetic force generated by the current-carrying coil immersed in a magnetic field, therefore the name, Kibble Watt balance. The apparatus is housed in a dedicated room under clean-room conditions and can measure a kilogram within a few parts in 108. In 2015, a simple LEGO model of the Kibble Balance was constructed by NIST scientists [L. S. Chao et all, American Journal of Physics 83, 913 (2015); doi: 10.1119/1.4929898] and there have been several attempts around the world to replicate the model.

We constructed a LEGO Watt Balance model as a research project for the UTC chapter of the Society of Physics Students. The project has been funded by the SPS National research grant. Later, it became an experiential learning 4000-level class. We not only constructed the apparatus, but working in close collaboration with NIST scientists, we improved the design and participated in writing new python code for the machine. We really enjoyed working on this project, and believe this is a very good undergraduate project, even for a small physics department. In this talk, we will share the obstacles we had to overcome and the lessons we have learned while making this inexpensive table-top model capable of measuring gram-level masses with 1% uncertainty.

10:30 – 10:45 **Break/Poster setup**

10:45 – 11:15 **Business Meeting** (Agenda will be distributed at the meeting)/Poster setup

11:15 – 12:00 **Poster Session**

Ian Alcox, Middle Tennessee State University
Studies of Quantum Materials with the MuST Software

In traditional studies, designing and fabricating new materials is often very expensive and time-consuming. With the advent of higher computational power, we have been able to use tools such as Density Functional Theory (DFT) to computationally model materials and predict their physical properties. It is the goal of the MuST Project to develop a software that can more accurately handle these systems while accounting for the disorder and complexity present in real-life systems. Specifically, more recent implementations of MuST have provided the ability to more precisely handle disorder effects in materials such as semiconductors and high entropy alloys (HEA). The goal of this research is to test and evaluate MuST's predictions of such materials via comparison to literature relating experimental results and predictions of similar software. Applying the MUST software to several semiconducting and HEA systems, we benchmark our results with other DFT methods finding a good agreement. We will continue to expand the existing capabilities of the MuST software and its application in an important class of quantum systems.

Oscar Allen, Middle Tennessee State University

By using transfer matrix method simulations that were performed on single and periodically arrayed Helmholtz resonators (HR) side loaded on an acoustic wave guide. The matrix method was implemented using the highly optimized language, Julia. Simulations demonstrate two distinguishable mechanisms of forbidden transmission formation—so-called acoustic band gaps. We hypothesized that periodic arrays of HRs would expand the band gap from a single HR. The spacing and number of HR influence the sizing of the band gap as well as the formation of higher order band gaps that didn't exist with a single HR. We also found that we can create defect states only within the acoustic band gaps that result from the periodic arrangement of HRs but not in the lowest band gap due solely to HR resonance.

Thomas Freeman, Middle Tennessee State University

The study of the Earth's ionosphere is an ongoing effort for scientists around the globe. The ionosphere is essential for radio communication and provides an important boundary between our atmosphere and the environment of space. Thus, analyzing how it works and what causes it to change is paramount for understanding communications, space weather, and solar- planetary interactions. The ionosphere has a daily cycle caused by ionization from sunlight during the daytime followed by recombination at nighttime. Our study is focused on how the lunar shadow over the Earth during the event of a solar eclipse might affect the activity of the ionosphere. In theory, this shadow should cause some transparency in the ionosphere, allowing for an increase in the incident radio waves from the galaxy, known as the galactic background. Through analyzing multi-frequency radio data collected from the recent 2023 annular eclipse, we hope to view these effects by studying this increase in galactic background activity during the time of the eclipse.

Michael Graff and Jair Martinez, Austin Peay State University
Measuring the Refractive Index Dispersion of a Glass Prism with a Six-Beam Laser in Four Ways on One Platform

We describe a versatile optical setup based around a laser module with five colinear beams (and one misaligned beam) of different wavelengths. We used this setup to measure the dispersion of the refractive index of a glass prism using four different methods: angle of minimum deviation, fitting to the minimum deviation curve, Fresnel reflectance, and Brewster's angle. Future work includes adapting this setup to also include total internal reflection and rotating analyzer ellipsometry. These experiments and computations can be adapted to various undergraduate projects ranging from three advanced laboratory sessions to semester/summer-long student research experiences.

De'Ja Graves and Jason Alexander, University of Tennessee at Martin
Real-time chemical analysis with open-source software and hardware

We describe two real-time chemical analysis instruments that utilize open-source software and hardware. These devices are the synthesis of a series of physical computing experiments. These experiments explored the use of various analog and digital inputs/outputs with two different platforms: The ATmega328P embedded microcontroller (with a C++ like programming language) and the Raspberry Pi computer (with the Python programming language) and custom graphical user interface (GUI).

Meleah Lanier, Austin Peay State University
Incorporation of Fe and Sn in Ge-Ga-Se-Te Glass Matrix

Chalcogenides, compounds comprising chalcogens (S, Se, and Te) along with elements from the III-V groups of the Periodic Table, have surged in importance due to their versatile properties applicable across diverse fields such as infrared (IR) optics, sensors, and phase-change memory devices. Their capacity to adopt crystalline or amorphous phases, contingent upon thermal history, underscores their adaptability to various technological needs. Of particular interest is the incorporation of metals like iron (Fe) and tin (Sn) into the chalcogenide matrix, offering potential for introducing new functionalities, particularly in magneto-optics. Four synthesized iron- and tin-based chalcogenide composites were characterized using optical spectroscopy, differential scanning calorimetry, x-ray diffraction, and Raman spectroscopy, as well as reflectance, transmittance, and absorbance measurements and calculations. These analyses shed light on the structural, thermal, and optical properties of the synthesized materials. The findings not only elucidate the crystallinity degree of the samples but also provide insights for potential applications, including thin film fabrication. While representing a novel glass, this research has laid a foundation for further exploration and utilization of chalcogenide-based materials.

Brian Matthews, Middle Tennessee State University
Particle-Dipole Interactions in Relativistic Collisionless Shocks

Evidence suggests that particle-dipole interactions in the upstream of unmagnetized plasma holds a key importance for energy gaining and sustaining particles. In particular, we study the particle-dipole interactions in the upstream region of relativistic collisionless shocks. We use a two-dimensional particle simulation to study the effects of the particle-dipole interactions. Each particle in our simulation begins with an energy of $\gamma = 15$ where γ is the Lorentz factor, which is used for quantities when the speed of an object becomes comparable to the speed of light. The upstream region consists of numerous dipoles that deflect a particle's path. The dipole deflections result in an overall change to the particles energy. A similar process is that of Fermi acceleration. A key difference between our results and energy gaining via Fermi acceleration is that our results show significantly faster growths in the energy then that of Fermi acceleration. In the certain cases of interest, we find that particles can gain a large amount of energy and end up keeping that energy. We study the particle-dipole cases in which the particle interacts with multiple dipoles in the upstream. The overall energy gain of the particles can cause the particles to accelerate. When comparing our results with the results of energy gaining via Fermi acceleration, we find that the two results differ significantly.

Shelby Mayhut, Middle Tennessee State University

This project aims to advance the method of converting biomass waste into a source of renewable energy by utilizing plasma, derived from red blood cells of livestock, for the storage and emission of electromagnetic radiation (light).

The livestock industry generates 1.4 billion pounds of biomass waste each year, resulting in copious water and air pollution. A preliminary study conducted by MTSU physics professor Dr. Daniel Erenso and undergraduate biology major Lindsey Tran demonstrates the unique capability of plasma to absorb 90% of electromagnetic radiation emitted from a 1064 nanometer infrared laser in a study titled "Harvesting and Storing Electromagnetic Radiation using RBCs in Animal Blood and Micromagnetic Beads". This study also demonstrates the capability of plasma to serve as a source of self-sustaining energy, as evidenced by a newly discovered "Star-like" formation that continued to emit radiation after the laser was turned off. These findings imply two things:

1.) Animal blood from livestock waste may serve as a viable source of electromagnetic energy storage and emission.
2.) The "Star-like" formation created during ionization of the plasma provides an exciting opportunity to simulate hands-on, experimental research on a star that would otherwise only be studied through observation.

Drawing on the studies discussed above and my previous research experience in the optics lab, I propose that testing larger volumes of plasma (10 ml, 100 ml, and 1000 ml) and incorporating new variables (such as using an ultraviolet laser to simulate natural sunlight) is necessary to develop practical applications for this new method of energy harvesting. The objectives of this study include measuring key characteristics of radiation emission from varying volumes of plasma samples, including incident and transmitted power, temperature, and duration of time.

This project also includes studies on the energy-storing capabilities of an aged sample of chicken blood. Power measurements are being conducted to analyze how the aged blood (refrigerated for 7 months) compares with fresh samples.

Ariel Nicastro and Monika Fouad, Middle Tennessee State University

In condensed matter physics, disorder refers to asymmetries in the crystal structure at the atomic level. There, materials can undergo phase transitions such as the Anderson Localization Transition (ALT), which is responsible for the conductor to insulator transition. Understanding the impact of disorder on quantum materials is critical for material design, as materials' properties can be manipulated to improve material durability, cost effectiveness, and other desirable characteristics. Such types of improved materials can be used in buildings, airplanes, and machinery. When studying the effects of disorder, it is important to have reliable numerical tools that can properly simulate disorder effects for various classes of quantum materials. To study the effect of disorder on quantum materials, we developed an effective medium quantum cluster method (CDMT) to simulate different types of disorder: binary, box, and Gaussian. These distributions represent different disorder scenarios in technologically important systems, such as alloys and semiconductors. In this project, we will show that our CDMT method captures the experimentally observed impact of disorder on a material's density of states, i.e. the broadening of the spectrum by disorder. We will also investigate the importance of non-local (beyond single impurity) scattering effects which we model by a finite cluster method.

Isaac Shirk, Middle Tennessee State University
Collaborative Augmented Reality for Astronomy Labs

In an effort to help students learn spatially complex scientific concepts, we have developed an Augmented Reality (AR) system designed for use in educational laboratory settings. Specifically, we are developing an AR-based lab module focused on Astronomy, allowing users to interactively explore the phases of the Moon in a three-dimensional space. While our current system has been tested on individual learners, our next objective is to support two-person collaboration. This feature aims to allow groups to see the same virtual content and promote peer discussion, further enhancing learning retention and engagement. We have encountered technical challenges syncing virtual objects across devices, but are close to a solution. Although data on two person interactions is yet to be collected, we have IRB approval for gathering comprehensive user engagement metrics through headpose, controller positions, and interaction timing, as well as graded assignments related to the lab. We are currently designing new modules that include topics in astronomy, chemistry, and physics, as well as adapting our software to new AR platforms. In the future, our goal is to broaden the AR system's subject range and capabilities in order for it to be a valuable educational resource.

Lindsey Tran, Middle Tennessee State University
Revolutionizing Energy Harvesting: Creating Artificial Stars from Livestock Blood and Micromagnetic Beads to Generate Electromagnetic Radiation

Electromagnetic (EM) radiation, omnipresent in our surroundings, serves diverse purposes from simple cellular communication to advanced medical treatments and space exploration! Our research explores an innovative way to revolutionize EM harvesting and storage through laser-trapping technology, micromagnetic beads, and livestock blood. The livestock industry annually generates an excessive 1.4 billion pounds of waste, primarily animal blood, representing a significant environmental concern. By utilizing blood samples from key livestock animals (sheep, goat, chicken, bovine, turkey, horse, and porcine), our study produces long-lasting and self-sustaining EM radiation. To accomplish this, the experiment involves a 3:1 micro-level mixture of animal blood and micromagnetic beads on a depression slide within an infrared laser trap, progressing through two distinctive phases: Plasma formation and Star-like radiation. In Plasma formation, exposure to the laser trap induces electric breakdown, which ionizes the sample mixture and forms a dense plasma. Subsequently, the Star-like radiation phase begins when the laser is reactivated onto the dense plasma. This accelerates the plasma and generates intense blackbody radiation. This radiation is seen as a yellow, glowing illumination that grows as more energy is absorbed, showing similarities to stars, such as the natural Sun. Hence, we named this phenomenon, "Star-like formation." The study attains 90-95% radiation energy absorption over 1.5 to 7.5 hours, marking a micro-level advancement in EM harvesting with animal blood. To expand on this, further measurements are now being conducted using greater sample mixture volumes and an ultraviolet laser trap to observe abilities across the electromagnetic spectrum. We envision this study to be a foundational step for macro-level applications, such as leading to the creation of artificial stars.

Ethan Weiche, Middle Tennessee State University

Two-dimensional (2D) ferroelectrics are, like their three-dimensional sibling, a material that shows spontaneous electric polarization which can be controlled by external electric fields. Initial studies on 2D ferroelectrics have focused on demonstrating the occurrence of ferroelectricity by various experimental probes, but the anisotropic interaction of 2D ferroelectrics with polarized light has been less understood. Two polarizers with perpendicular polarizing axes obstruct any light from passing through both filters consecutively. However, when anisotropic (birefringent) materials are placed between cross-polarizers, transmission/reflection properties may be altered due to anisotropic refractive indices. This, in turn, could provide valuable insight into the underlying ferroelectric polarization. This research aims to develop methods to characterize 2D ferroelectric domain structures and quantify their refractive indices via their interactions with polarized light.

12:00 – 12:10 **Poster Prize Presentation**

12:10 – 1:00 **Lunch**

1:00 – 2:30 **Hanna Terletska, Quantum Science Workshop**