UNDERGRADUATE RESEARCH SYMPOSIUM

COLORADO SCHOOL OF MINES

2024 | Program

04. 17. 2024 & 04. 18. 2024

Ben H. Parker Student Center

Undergraduate Research Scholars and University Honors and Scholars (UHS) presents the seventh annual spring symposium showcasing undergraduate research from all disciplines across Mines.

SEVENTH ANNUAL SPRING

UNDERGRADUATE RESEARCH SYMPOSIUM

Celebrating the accomplishments of undergraduate students and their mentors.

This year's undergraduate research symposium was made possible by the generous support of Dr. Joe W. Gray '68.

Dr. Joe W. Gray is a professor emeritus at the Oregon Health and Science University and University of California, San Francisco, and chair of the National Academies of Sciences, Engineering, and Medicine's Committee on Developing a Long-Term Strategy for the Low-Dose Radiation Research in the United States. Dr. Gray has an impressive research career and his work has been cited over 119,000 times. A few notable honors include, Fellow, American Association of Cancer Research Academy Class of 2015; Alfred G. Knudson Award Lecture in Cancer Genetics, National Cancer Institute, 2014; Simon M. Shubitz award for work in genome science, University of Chicago, 2012; and the recipient of the Mines Distinguished Medal of Achievement 2005. He is a 1968 Mines physics graduate and currently serves on the Board of Governors.

Go Orediggers!

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WELCOME

It is with great pleasure the Office of Undergraduate Research Scholars and University Honors & Scholars invites you to the seventh annual spring Undergraduate Research Symposium.

Since the inaugural symposium in 2018, featuring 80 poster presentations, the spring symposium has grown into a two-day event, this year featuring 120 intellectually stimulating oral and poster presentations. In addition, Undergraduate Research Scholars now also hosts a fall Undergraduate Research Symposium, with the third annual fall symposium upcoming in September 2024.

We are honored to welcome Dr. Buffie Longmire-Avital to deliver our Keynote Address, **Intentional Design for Including Historically Underrepresented Excluded Minority Students in High Impact Practices.**

We are also grateful for the sponsorship from Dr. Joe W. Gray ’68. His support is an integral part of making this event possible.

We hope you enjoy the opportunity to connect with Mines undergraduate students and learn a bit more about the crucial research being undertaken by these emerging researchers.

Office of Undergraduate Research Scholars
University Honors & Scholars

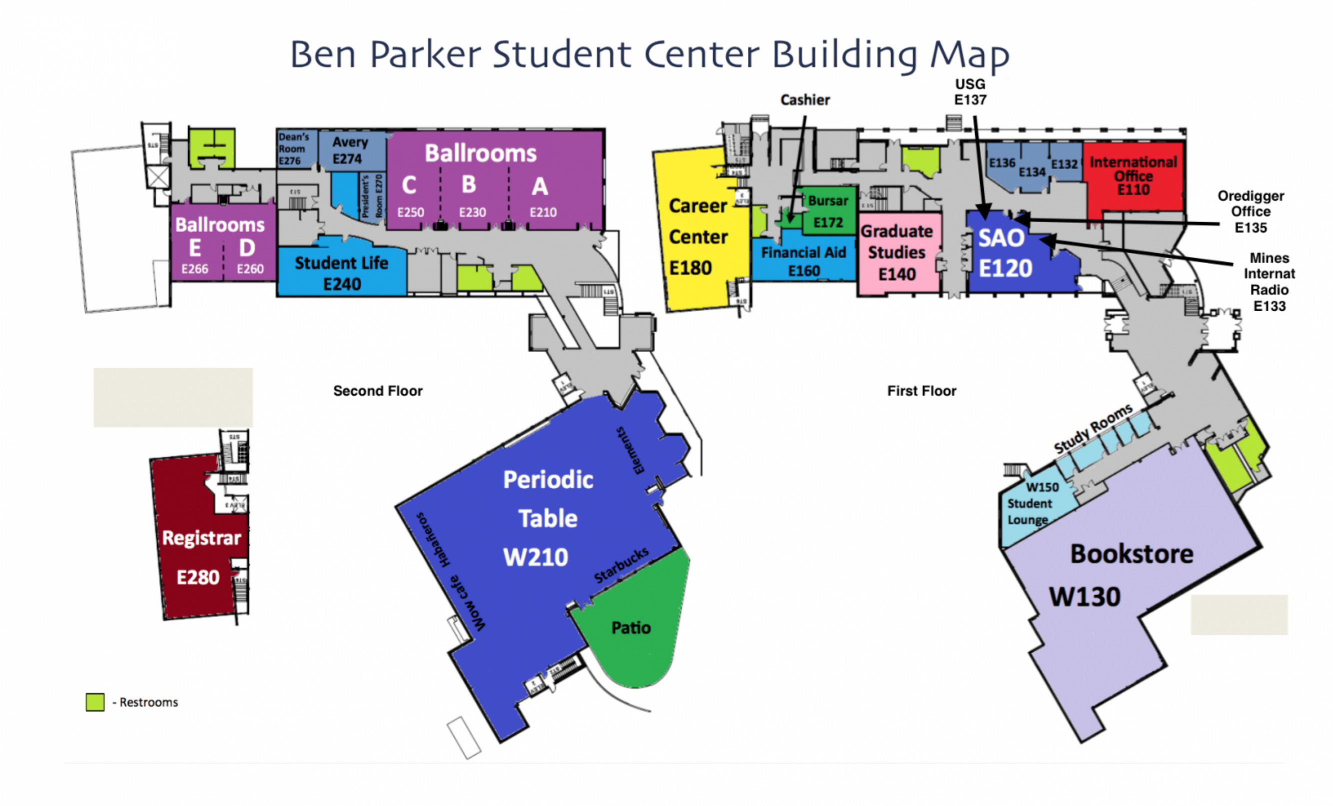
KEYNOTE ADDRESS

Buffie Longmire-Avital, PhD (she/her)
Professor of Psychology, Elon University

"Intentional Design for Including Historically ~~Underrepresented~~ Excluded Minority Students in High Impact Practices"
Wednesday, April 17th 12-1pm, Ballrooms D&E

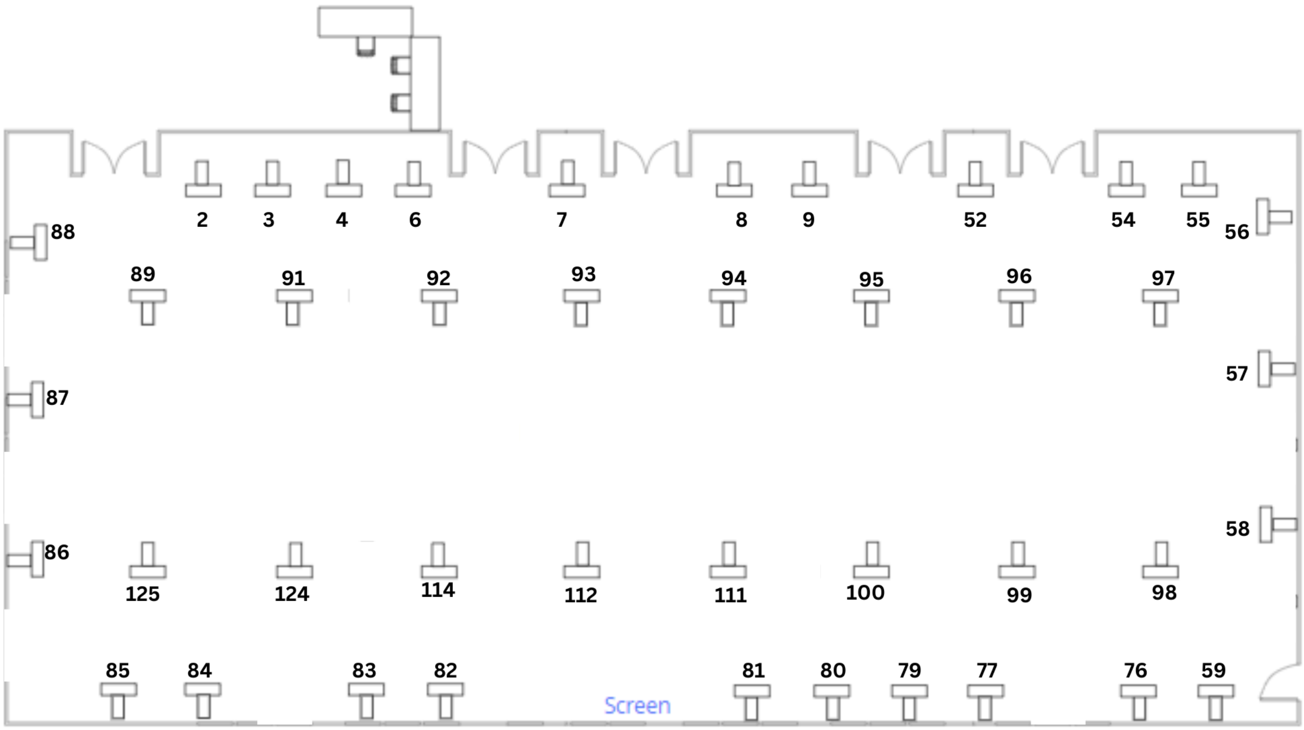
In this keynote address, Dr. Longmire-Avital will share best practices for working with and supporting historically underrepresented minority students (HURMS) engaging in high impact practices. Historically Underrepresented Minority (HURM) students, are members of groups that have, "historically comprised a minority of the US population" (NACME, 2013). Using autoethnography, she will reflect on her own journey as a HURM student and now faculty mentor as she engages her process of documenting and defining what sustainable critically conscious-equity and access looks like. To Dr. Longmire-Avital, it is a synergistic and reparative framework for critically mentoring HURMS that integrates the works of Ladson-Billings and Tate (1995); Hurtado et al., (2015); Weiston-Serdan, (2017); and Yosso, (2005). Central to this emerging framework is her acceptance of the fact that education in the United States is not an equitable system. Educational opportunities are not evenly distributed among students and access has historically, as well as presently, favored persons with racial, gender, and economic privilege. Increasing and sustaining the engagement of HURMS in HIPs must be an intentional act towards dismantling a longstanding system that has forged its credibility and identity on being selective, elite, and elusive. The intentional dismantling act comes in the form of creating and giving space to persons that have historically been denied it. In fact, she argues that these are not historically underrepresented students but historically excluded students and we must engage the act of keeping students in the game, a game that they may not understand how to play effectively yet, a game that was not created with them and their needs in mind, a game that has *historically devalued the skills, qualities, and capital they do bring to it*. For Dr. Longmire-Avital, the act of giving or generating permanent space for HURMS is a radically reparative one.

MAPS – BEN PARKER STUDENT CENTER

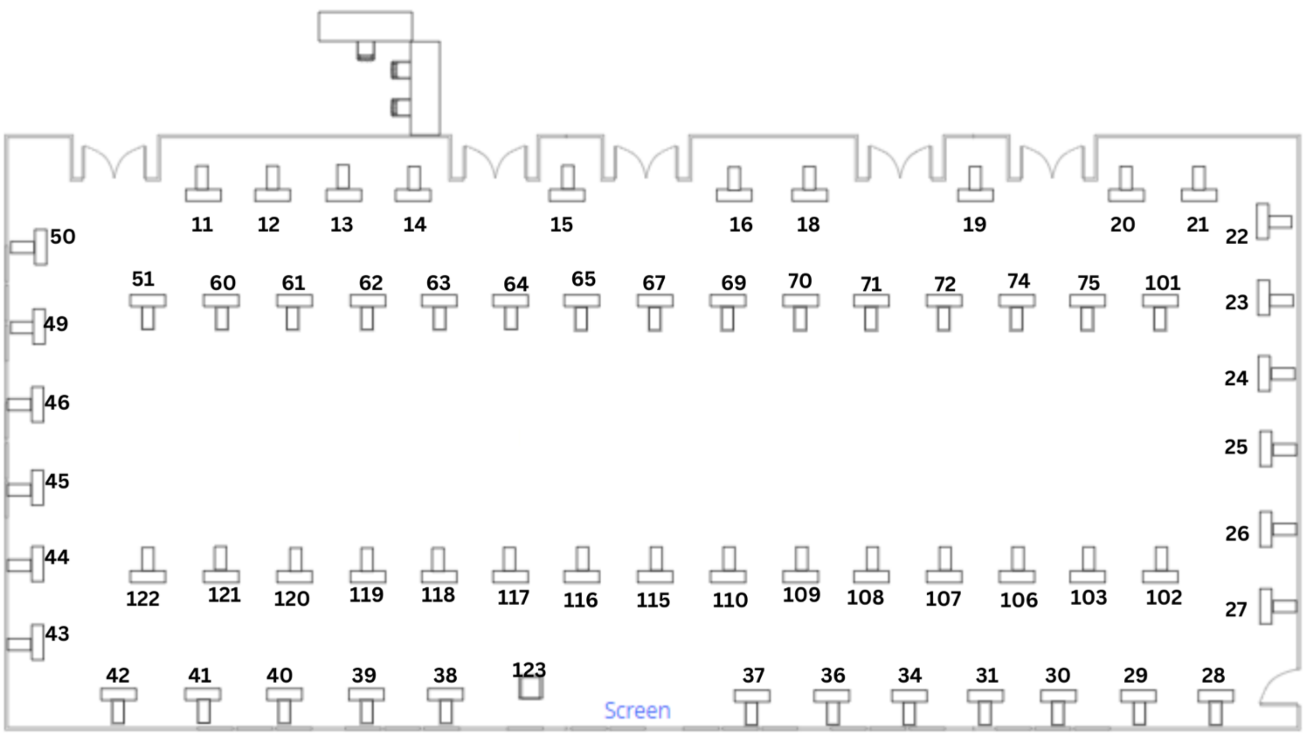


UNDERGRADUATE RESEARCH SYMPOSIUM
COLORADO SCHOOL OF MINES

MAPS – POSTER SESSION #1 (MORNING)



MAPS – POSTER SESSION #2 (AFTERNOON)



SCHEDULE OF EVENTS

WEDNESDAY, APRIL 17TH, 2024

Poster Presentation Session #1
9:30am – 11am, Ballrooms A, B, C

Departments Presenting: Applied Math and Statistics, Civil and Environmental Engineering, Economics and Business, Engineering, Design & Society, Geology and Geological Engineering, Geophysics, Humanities, Arts and Social Sciences, Mechanical Engineering, Mining Engineering, Petroleum Engineering

Keynote Address by Dr. Buffie Longmire-Avital
12:00pm-1:00pm, Ballrooms D & E

Poster Presentation Session #2
2:00pm-3:30pm, Ballrooms A, B, C

Departments Presenting: Chemical and Biological Engineering, Chemistry, Computer Science, Electrical Engineering, Metallurgical and Materials Engineering, Physics

THURSDAY, APRIL 18TH, 2024

Breakfast Mentor Workshop
9:00am – 10:00am, Ballrooms D & E

Oral Presentations
12:00pm-2:00pm, Ballrooms A, B, C

ORAL PRESENTATIONS SESSION 1

THURSDAY, APRIL 18TH, 2024 12pm – 1pm
Student Center Ballroom A, B, C

Ballroom A

Time	Presenter	Project Number and Title
12:00pm	Roya Akrami	#68, Quantum Cascade Laser-Based Vibrational Circular Dichroism
12:15pm	Claire Nelson	#33, Cell Culture Substrates Functionalized with Glycosaminoglycan-Mimetic Polymer Brushes to Augment Human Mesenchymal Stem Cell Self-Renewal
12:30pm	Stephanie Morrall	#32, The Role of Extracellular Matrix Stiffness in Modulating Ca2+ Dynamics and Insulin Secretion in Mouse Islets
12:45pm	Ryan Carbajal & Wayne Snodgrass	#113, Hydrogen Storage in Subsurface: Influence of Rock and Geofluid Chemistry

Ballroom B

Time	Presenter	Project Number and Title
12:00pm	Jamie Regan	#10, Access Granted: Navigating the ADA Maze in STEM Higher Education
12:15pm	Michael Basanese	#1, Comparing different sensor types for continuous monitoring of methane emissions at oil and gas sites
12:30pm	Kylie Knutson	#47, Unraveling the Catalytic Mechanism of Nitrile Hydratase
12:45pm	Cailyn Smith	#66, Evaluating the Effects of Performative Autonomy for Robots with Communication Latency

Ballroom C

Time	Presenter	Project Number and Title
12:00pm	Bella Chase	#17, Exploring the Effects of Surfactants in Crude Oil on Gas Hydrate/Pipe Wall Interactions
12:15pm	Maddy Hoffman	#105, In-Situ Hydrogen Quantification, Migration, and Hydride Studies
12:30pm	Alex Luong	#48, Characterization of peptide catalyst
12:45pm	Ryan Miller & Alexis Capitano	#73, Implications of Engineering and Education Professor's Problem-Solving Mindsets on Their Teaching and Research

ORAL PRESENTATIONS SESSION 2

THURSDAY, APRIL 18TH, 2024 1pm – 2pm

Student Center Ballroom A, B, C

Ballroom A

Time	Presenter	Project Number and Title
1:00pm	Madie Addis	#53, Global Material Flow Analysis for Macro and Micro Plastics with Emphasis on Plastics Lost to the Environment
1:15pm	Lucy Gilbert-Fagan	#78, Explorations of Engineering Identity Formation and Gender Expression
1:30pm	Amit Sela	#35, Changes in extracellular matrix stiffness mediate pancreatic islet function: Insights into glucose metabolism and mitochondrial dynamics

Ballroom B

Time	Presenter	Project Number and Title
1:00pm	Ben Longaker	#5, Global Sensitivity Analysis of Plasma Instabilities
1:15pm	Fischer Argosino	#90, Policy Recommendations for an Equitable Energy Transition in Denver
1:30pm	Xavier Fross	#104, Advanced Gas Metal Arc Welding Processes to Clad Molten Salt Reactor Components

ABOUT SURF

Summer Undergraduate Research Fellowship

The Summer Undergraduate Research Fellowship (SURF) program at Mines seeks to provide funding for current Mines undergraduate students to participate in concentrated, full-time research under the mentorship of the Mines faculty. This fellowship is open to students of all disciplines. In addition to focusing on an in-depth research project, students will also have the opportunity to attend professional development seminars with the SURF and NSF REU cohort students.

The SURF program aims to promote and support undergraduate students' scholarly and creative pursuits by providing summer research fellowships. The SURF program champions the goals outlined in the MINES@150 campaign by engaging students in cutting-edge research and innovation at Mines aimed at solving significant challenges facing humanity and thereby shaping the next generation of diverse STEM leaders. This program is open to all current undergraduate students at Mines.

Program Goals

- Provide research opportunities for Mines undergraduate students who are interested in pursuing a career in research.
- Increase access to graduate programs for minoritized students by providing opportunities to experience scholarships.
- Provide professional development opportunities through weekly workshops to help students prepare for post-graduate opportunities.
- Prepare Mines students to be competitive for prestigious research fellowships (e.g. Goldwater, NSF REUs, NSF GRFP, etc.).

Program Details

- Students funded by the SURF program are expected to conduct a total of 300 hours of research during the summer semester (May-Aug). For example, students can choose to conduct 30 hours of research for 1- weeks or 40 hours of research for 7.5 weeks.
- Each SURF student will receive an award of $4,000.
- SURF students are expected to attend the professional development seminars that take place during their proposed research timeline. These seminars are related to career preparation, scientific ethics, abstract writing, giving a scientific talk, and select research talks.

All SURF students will present their work at the end of the summer program and at the Mines Undergraduate Research Conference.

www.mines.edu/undergraduate-research/undergraduate-research-opportunities/surf/

ABOUT MURF

Mines Undergraduate Research Fellowship

The objective of the Mines Undergraduate Research Fellowship (MURF) is to enhance the education of undergraduate students with an opportunity to engage in research on faculty-led research projects. This program broadens and deepens the educational experience of students by exposing them to the research enterprise. Engaging in research could turn into a journey of self-discovery for students as it may help them to identify their own career or research aspirations.

Research that is funded by MURF cannot be taken for research credit or count towards a senior design credit. Participating faculty members are encouraged to increase the research participation of qualified female-identifying students and students from under-represented backgrounds.

Terms of Eligibility

All full-time undergraduate students currently enrolled at Mines are eligible to apply.

- The fellowship stipend for MURF is $1,500, disbursed biweekly during the academic year.
- Renewals for a second period are allowable upon demonstration of adequate progress and have to be applied for through the next solicitation.
- Students who are available to conduct research during both the fall and spring semesters will be given preference.

Program Details

Students who receive the fellowship are expected to:

- Provide a 1-2 page summary of the research at the end of the fall semester
- Present a poster or give a talk at the spring undergraduate research symposium
- The student application for MURF (2024-2025) is open from April 15 – May 24, 2024.

You can learn more about MURF, search available research projects, and submit a student application at:

https://www.mines.edu/undergraduate-research/undergraduate-research-opportunities/undergraduate-research-fellowship/

ABOUT FIRST

First-Year Innovation & Research Scholar Training

First-year Innovation & Research Scholar Training (FIRST) offers an opportunity for highly motivated first-year students to participate in original research experiences with a focus on innovation. FIRST scholars are paid hourly for conducting research.

FIRST Fellowship Structure

In the fall semester, students enroll for a one credit course that will introduce them to academic research and provide tools needed to navigate the complex landscape of research.

- Students will identify a faculty or graduate student mentor during the fall semester and work with the mentor to distinguish a research topic, formulate a hypothesis and ascertain objectives by the end of the semester.
- Students are expected to participate in 4 hours of faculty-mentored research per week in both the fall and spring semester.
- Students conclude their fellowship by presenting their research and innovation project at the spring Undergraduate Research Symposium held annually in April.
- Selected students may receive additional funding to continue working with their mentors for the summer semester.

You can learn more about FIRST and submit a student application at the following URL:

https://www.mines.edu/undergraduate-research/undergraduate-research-opportunities/first/

THANK YOU TO OUR MENTORS

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2024 UNDERGRADUATE RESEARCH SCHOLARS MENTOR AWARD

The Undergraduate Research Scholars Mentor Award recognizes faculty, postdoc, and graduate students for their exceptional mentoring of undergraduate students in enriching research experiences. Organized by the Office of Undergraduate Research Scholars, this award provides an avenue for undergraduate students to recognize and nominate their outstanding research mentors.

The Undergraduate Research Scholars Mentor Award is open to all Mines faculty, post-doctoral researchers, and graduate students mentoring undergraduate students on a research project.

Nominations are solicited widely from current undergraduate students. The recipients are recognized as part of the Undergraduate Research Symposium in April and profiles are published in the Symposium Program Book and the Undergraduate Research Scholars website.

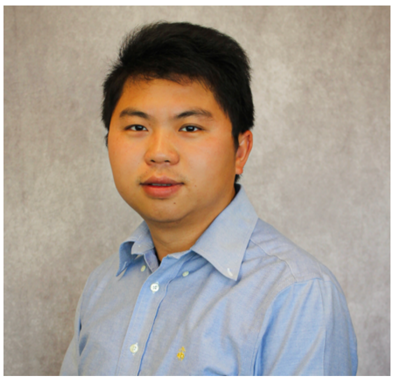
FACULTY AWARDEES

Terry Lowe
Research Professor
Metallurgical and Materials Engineering
"Dr. Lowe has had a profound impact on my personal, professional, and academic life. He brought me on to his team as a first-year student and provided many opportunities for me to develop new skills and perform research. My self-confidence, ability to present findings, and competency in materials science have increased greatly since joining his research team.

Eileen Martin
Assistant Professor
Geophysics and Applied Mathematics and Statistics
"The support [Dr. Martin] has offered has been instrumental in instilling confidence as I approach graduation, equipping me with a myriad of both soft and hard skills that I will carry with me throughout my career. Dr. Martin's mentorship exemplifies the profound impact that a dedicated mentor can have on a student's academic journey, and I am incredibly grateful to have her support as I strive to achieve my academic goals."

Scott Strong
Teaching Professor
Applied Mathematics and Statistics
"I'm really grateful my first research experience was with Dr. Strong because he made it clear from the beginning that it's okay and normal to struggle and feel like I'm not making progress for periods of time while doing research. I've gained confidence from this experience and I've grown as an independent learner."

POSTDOC AWARDEE



Shilai Hao
Postdoctoral Research Associate
Civil and Environmental Engineering
"Working with Shilai has blown my expectations out of the water with respect to how much I have learned from working with him. Shilai is constantly teaching me new topics and laboratory procedures while continuously offering me the opportunity to learn about and participate in additional projects.It is always clear to me that Shilai's goals for me are for me to learn as much as possible while working with him."

GRADUATE STUDENT AWARDEES

Julia Hylton
Graduate Student
Materials Science
"The amount of relevant research skills in the realm of analysis, technical writing, and career development I have learned from [Julia] has built a foundation of confidence for me to build a path of my own. Her enthusiasm keeps me excited and inspired to keep going with my work, even at times where work can seem slow or ineffective."

Molly O’Halloran
Graduate Student
Geology
“Molly enjoys what she does and her enthusiasm is contagious. She assumes that everyone is capable of learning. Deciding to go into geosciences is something I joked about for a while, but Molly took me seriously, constantly encouraging me to push myself toward my goals. I would never have envisioned myself successfully doing the work I did during SURF, but with the guidance of Molly, I was pushed out of my comfort zone and built an entirely new skillset.”

Elliese Wright
Graduate Student
Civil and Environmental Engineering
“Elliese excels at teaching and has been essential to my ability to learn the systems in place. I am given the freedom to pursue excellence and the assistance to achieve it. I would be lost in the research world if not for Elliese and I feel empowered as a woman in STEM and research because of her incredible mentorship.”

2024 STUDENT PRESENTERS

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TECHNICAL PROGRAM

APPLIED MATHEMATICS AND STATISTICS

#1(O) Comparing Different Sensor Types For Continuous Monitoring Of Methane Emissions At Oil And Gas Sites

Author(s): Michael Basanese, Junior, Applied Mathematics and Statistics
Mentor(s): Dorit Hammerling, Will Daniels

Reducing methane emissions from the oil and gas sector is an essential tool for combatting climate change. For oil and gas companies to effectively reduce their methane emissions, they need to first measure their emissions, both to provide an emissions baseline and to identify large emission sources. Continuous monitoring systems (CMS) are one method for measuring methane. These measurement systems use multiple fixed sensors placed around the perimeter of an oil and gas site to measure methane concentrations in near real time. In practice, many different companies produce these sensors, some using less expensive metal oxide (MOx) sensors and others using more expensive laser-based sensors. In this study, we investigate whether there are significant differences in the methane emission characteristics inferred from these two types of sensors. As a case study, we focus on one site with both MOx and laser sensors installed. We use an algorithm that translates the raw concentration data from the CMS sensors into more practically useful information, such as identified emission events, predictions about what structure is emitting, and emission rate estimates. We compare the output from this algorithm when using the two different sensor types as inputs and identify significant differences in the inferred methane emission characteristics. We determine that low quality data from the MOx sensors, particularly at night, are a potential cause of these differences. By incorporating these findings, companies that use CMS can improve the accuracy of their methane emission data, leading to more efficient emission reduction pathways.

#2 Coarse-Graining of Biomolecular Complexes Through Active Subspace Learning

Author(s): Quinn Harrand, First Year, Quantitative Biosciences and Engineering
Mentor(s): Steve Pankavich, Alexander Pak

The research objective of this project is to expand the understanding of biomolecular assembly and organization through simplified coarse-grained (CG) models derived from traditional all-atom molecular dynamics (AAMD) simulations. Current AAMD simulations are unable to feasibly capture high-resolution interactions and deformations due to the large timescales necessary to understand emergent behavior in complex macromolecules. In contrast, coarse-grained models, whereby simplified CG sites are determined by mapping onto atomic distances and the effective forces that emerge from CG sites, permit the large time evolution of such systems, but remain difficult to apply to macromolecular assembly due to superfluous CG variables. The active subspace method, a supervised dimension reduction approach, enables efficient pruning of the set of CG variables by identifying the most important directions in the CG space that influence the corresponding potential mean force. Upon evolving over large times, CG models still fail to capture microscopic details, therefore requiring a back-mapping approach that employs machine learning techniques to recover the all-atom configuration from the low-resolution CG configuration with high probability. Together, these methods will magnify the unique morphologic and hierarchical arrangements of biomolecules, enabling advances in biotechnology.

#3 Dispersion And Stability Of Helical Excitations Of Vortex Filaments Driven By Curvature Dependent Binormal Flows

Author(s): Schede Harvey, Junior, Physics
Mentor(s): Scott Strong

In this project, we extend the results of Paul K. Newton and Joseph B. Keller's stability analysis to study the dispersion and stability of plane wave solutions to nonlinear differential equations of Schrödinger type. These solutions describe the curvature and torsion of a vortex filament. Curvature describes the rate at which the curve changes direction in the plane defined by the tangent and normal vectors and is defined as the amplitude of the plane wave. The torsion describes how much that plane is twisting in space and is the derivative of its phase. Plane waves in this context are traveling helical modes of the vortex filament, which are thought to mediate turbulent energy transfer within the fluid. Our goal is to understand waves on vortices by understanding the corresponding fully nonlinear dynamics of perturbed helical waves. To do this, we must generalize known results to accommodate vortex filament wave equations whose highest-order derivative acts on nonlinear terms.

#4 Simulating Vortex Filament Motion

Author(s): Daniel Krawciw, Junior, Applied Mathematics and Statistics
Mentor(s): Scott Strong

Vortex filaments occur in a wide array of contexts, from quantum liquids to underwater bubble rings. Simulating the three-dimensional velocity fields generated by filaments is inefficient due to the large number of points needed to resolve the space. Because the points in question lie on the filaments, it is fruitful to focus on those points making up the filament and evolve them through the space according to the induced velocity field. The challenge associated with their simulation is the underlying Biot-Savart representation of the field generated by the filament. Specifically, since the denominator of the Biot-Savart equation contains singularities associated with measuring the velocity at points lying on the filament generating the field, one must determine how to arrive at approximate finite results. Different finite approximations have benefits and drawbacks, as terms that are easier to work with tended to be harder to justify geometrically, whereas geometrically intuitive terms were more difficult to work with. In this project, we discuss numerical approximations to the Biot-Savart integral and the use of this induced field to provide dynamics to the vortex filament.

#5(O) Global Sensitivity Analysis of Plasma Instabilities

Author(s): Ben Longaker, Senior, Applied Mathematics and Statistics
Mentor(s): Stephen Pankavich

Active subspace analysis is a computational tool that can identify the input parameters in a given high-dimensional model that are most influential on a specified output variable. This method uses random sampling and average correlations to determine the linear combinations of parameters that generate the greatest change in the output variable of interest. Because the stability of plasmas can influence certain engineering decisions in applications like internal confinement fusion, and the dynamics of plasma models can change drastically with different inputs, active subspace analysis can be a useful tool in determining how changes in physical parameters affect plasma behavior. In this project, we use active subspaces to analyze a fundamental model of plasma dynamics, the one-dimensional Vlasov-Poisson system, with various steady-state velocity distributions to determine the linear combinations of parameters that most affect the plasma's rate of stability or instability. We focus on steady-state distributions that are computationally difficult to implement, such as the Incomplete Maxwellian and Kappa Bump-on-Tail distributions, which also requires the development of new computational methods to accurately and efficiently solve the plasma models.

#6 Global Sensitivity Analysis of Plasma Instabilities

Author(s): Nolan Palmer, Senior, Physics
Mentor(s): Steven Pankavich

When electrons in hot neutral collisionless plasmas are perturbed slightly, the particle density of the plasma responds according to electrostatic laws. Such a response is governed by the Vlasov-Poisson system, a fundamental model of plasma dynamics that enables one to determine whether the plasma is stable or unstable with respect to such perturbations. Because the initial steady state of the plasma is highly dependent upon a variety of physical parameters, our project focused on developing computational techniques to compute the rate of stability or instability of the plasma as a function of the parameter space. To this end, we employ active subspace and Monte-Carlo methods to approximate the rate of (in)stability across a whole subspace of input parameters and identify along which directions in parameter space the stability changes the most. We focus on initial velocity distribution functions such as the Maxwellian Bump-on-Tail (common in laboratory plasmas), the Incomplete Maxwellian (in plasmas near a wall), and variations of the Kappa or Lorentzian (used to model solar wind and other space plasmas). Our results can be used to motivate parameter control in a laboratory setting to keep plasmas stable and predict the response of naturally occurring plasmas to disruptions.

#7 Backmapping Active Subspace Coarse-Grained Variables To All-Atom Configurations

Author(s): Logan Pike, Senior, Applied Mathematics and Statistics

Mentor(s): Steve Pankavich, Alex Pak

Current research in the field of computational molecular biophysics centers around simulating the dynamics of large collections of macromolecules, such as those that can self-assemble into complex macromolecular structures. All-atom simulations of macromolecular complexes can be computationally intensive. However, atomistic models can be coarse-grained to reduce computational burden at the expense of atomic detail. An approach called backmapping aims to transform coarse-grained configurations to all-atom resolution, of which there are several solutions due to degeneracy. We utilize a supervised dimension reduction approach called active subspaces to enable coarse-grained simulations of self-assembling systems at reduced computational cost. The active subspace method identifies the most important directions in an input parameter space that influence a corresponding output function. The objective of this project is to construct generative machine learning models that predict all-atom representations of active subspace coarse-grained variables. Various neural network architectures are used to backmap to pairwise distances from active subspace coarse-grained variables. With these methods, we demonstrate greater than 99% atomic reconstruction from a reduced set of variables representing 16% of the original degrees of freedom on a dialanine test system.

#8 Soft Magnetic Microrobots Move More Efficiently With A Flat Tire

Author(s): Leah Schartz, Junior, Mechanical Engineering
Mentor(s): Brennan Sprinkle

Soft magnetic microrobots move more efficiently with a flat tire, conducted with mentor Brennan Sprinkle, concerns the numerical modeling of Pickering emulsions, small (~10-100um) fluid droplets covered with surfactant particles. Droplets are modeled as a triangular mesh and their bending, deviations from a spherical shape, is penalized with mesh-based forces that are chosen to ensure minimal surface area changes. The goal of this research is to implement efficient numerical models that are fast enough to simulate large droplets for biomedical applications.

#9 Camera - Based Detection and Quantification of Operational Emissions on an Oil and Gas Compressor Station

Author(s): Dishita Sharma, Sophomore, Computer Science
Mentor(s): Dorit Hammerling, Kellis Ward

Rapidly reducing methane emissions is a critical tool for curbing climate change and its destructive effects. Reducing methane emissions from oil and gas compressor stations is a particularly promising avenue in part due to the rapid development of emission monitoring technology. Here we investigate the ability of a camera-based measurement technology to detect and quantify emissions from compressor seal vents, blowdown vents, and valve actuations, three primary emission sources on oil and gas compressor stations. We compare emission rate estimates of the camera technology to operational data from the dry gas seals to analyze the difference between the camera-based emission rate estimates and the

quantification estimates produced by the on-site operational team.
We also assess the impact of different compressor states on the estimated emission rates from the camera technology and summarize emission information from blowdown events. The assessment of data allows us to make determinations for potential use cases of the camera-based technology. This camera-based technology could also be used to detect unexpected emissions from the oil and gas compressor stations. This thorough analysis can lead us to faster methane emissions detections, allowing for rapid methane mitigation efforts and ultimately fewer emissions.

#124 Mysteries of Venus: Exploring Seismic Wave Propagation with SPECFEM2D Simulations of the Planet's Dense Atmosphere

Author(s): Margaret Sauer, First Year, Physics
Mentor(s): Ebru Bozdag, Austin Hoyle

Through the dense atmosphere of Venus is a multitude of possibilities for seismic wave propagation. This high density may allow for probes and tracers of seismic activity from the surface of Venus that are unable to be reached because of the immense amounts of pressure and extreme temperatures through seismic readers in a type of weather balloon. In this research, the SPECFEM2D simulation software was used to be able to hypothesize and visualize the possible wave propagation that could be seen through the atmosphere. With the possibility of the density and velocity being too slow the waves may not be recorded thoroughly, however, this exploration will show the difficulties of Venus' geography and topography with data collection. Along with aiding to more innovative approaches to future space exploration on other planets and in their atmosphere.

#125 Rhizomes of Ranked Posets

Author(s): Rachel Castro , Junior, ComputerScience
Mentor(s): Aram Bingham

We introduce and study the notion of a \emph{rhizome} for a ranked, partially ordered set (or poset) where each set of fixed rank is finite. A rhizome is defined as a minimal size subset of the elements of rank n such that each of the elements of rank $n+1$ covers at least one element of the rhizome. Given a poset $\mc{P}$ with ranked parts $\mc{P}_n$, we consider the function $r_{\mc{P}}:\N\to \N$ which gives the size of a rhizome for $\mc{P}_n$, and study this function for examples like the Boolean lattice and Young's lattice.

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#10(O) Access Granted: Navigating the ADA Maze in STEM Higher Education

Author(s): Jamie Regan, Senior, Electrical Engineering
Mentor(s): Brianna Buljung, Seth Vuletich

This presentation comprehensively analyzes the challenges and opportunities surrounding transitioning students with disabilities from high school to higher education, focusing on STEM disciplines. Studies have shown that there is a gap in higher education enrollment and degree completion rates between students with disabilities and their peers who do not identify as disabled, which becomes even more pronounced in the STEM workforce. This presentation explores the many challenges students with disabilities face, such as regulatory shifts from the Individuals with Disabilities Education Act (IDEA) in K-12 to the Americans with Disabilities Act (ADA) and Section 504 in higher education, which can result in reduced support and increased independence. Other barriers include institutional obstacles like inaccessible materials, inadequate faculty training, and a need for dedicated support personnel. Through a detailed literature review, the study identifies critical areas of concern: community engagement, faculty training, self-advocacy, and visibility of support services. Universal Design for Learning is discussed as a proactive approach to creating accessible educational materials and environments. Primary research conducted in the study involves surveys distributed to Mines students and local high school faculty who work with students with disabilities. Preliminary findings reveal insights into accommodation trends, preparedness for higher education, understanding of legal rights, and the challenges in building a supportive community. The presentation also delves into the complexities of different disabilities and how the respondents believe accessibility can be improved. The aim is to apply these findings to make the Colorado School of Mines, and potentially other institutions, more inclusive for students with disabilities. This study contributes to the broader conversation on accessibility in higher education, particularly in STEM fields, advocating for systemic changes to support this underserved population.

CHEMICAL AND BIOLOGICAL ENGINEERING

#11 Active Subspace Coarse-Graining with Spherical Harmonics

Author(s): Leah Bandy, Senior, Chemical and Biological Engineering
Mentor(s): Alex Pak, Steve Pankavich

Many groups of molecules exhibit self-assembly behavior to form large-scale hierarchical structures. Scientists are interested in identifying the molecular basis for self-assembly, but the spatial and temporal resolution of current experimental techniques precludes observation of assembly details at the nanoscale. Meanwhile, conventional all-atom computer simulations remain too costly, and coarse-grained simulations, which trade detailed information for lower computational complexity, remain difficult to apply to macromolecular assembly. We utilize a supervised dimension reduction approach called active subspaces to enable coarse-grained simulations of self-assembling systems at reduced computational cost (compared to all-atom) and increased accuracy (compared to other coarse-grained models). The active subspace method identifies the most important directions in an input parameter space that influence a corresponding output function. The goal of this project is to develop and formalize the active subspace framework to derive coarse-grained models from all-atom data for reversibly aggregating alanine peptides. Our strategy is to explore spherical harmonics as the input parameter space, corresponding to potential energies as the output. Preliminary results indicate that a reduced set of spherical harmonics can provide a descriptive basis useful for coarse-grained modeling and simulation.

#12 Mechanical Design Support for Open-Source In-Vitro/In-Vivo Imaging System (openIVIS)

Author(s): James Brague, Junior, Physics
Mentor(s): John Branning

This research project delves into the mechanical design aspects and 3D printing techniques employed in developing a 10-wavelength filtering system for openIVIS. The work conducted was focused on supporting the Cash microbiology lab in their endeavors by providing additive manufacturing and mechanical design support. In this system, a combination of 3D printed parts and commercially available microelectronics are used in tandem with a Raspberry Pi to provide a user-friendly and affordable imaging system with world-class scientific capabilities. One of the objectives of this project was to design and implement a light filtering system that could enhance the imaging capabilities of the open-source platform by filtering out multiple specific wavelengths of light in rapid succession. To achieve this, we utilized principles of mechanical design to conceptualize the filtering system, considering factors such as size constraints, compatibility with existing components, and ease of integration. Throughout the process, we encountered difficulties with the actual fabrication and implementation of the system beyond the concept and design phases. The results of this research showcase a partially successful implementation of the light filtering system, demonstrating new ideas for light filtration and fluorescent imaging. The project highlights the importance of interdisciplinary collaboration between departments in advancing technological solutions for scientific applications.

#13 Simulation of Silicon Clathrate Materials for Photovoltaic Applications

Author(s): Connor Burns, Senior, Physics
Mentor(s): Carolyn Koh, Reuben Collins

Silicon clathrates are an allotrope of silicon with notable material properties that make it a candidate for use in next-generation photovoltaic cells. Diamond silicon, the traditional substrate material of choice, has an indirect bandgap and is non-ideal in a number of ways. Research on direct bandgap semiconductors with more favorable absorption properties, such as on silicon clathrates, may offer an alternative path for improving photovoltaic efficiency. Critical to the design of photovoltaic devices is an in-depth understanding of the material properties of the cell's underlying substrate. We leverage computational methods to predict phonon band structures and electron relaxation properties in silicon clathrate materials. Our work uses techniques from ab-initio density-functional theory which are implemented by ABINIT. Due to the moderately irregular symmetry properties of crystalline clathrate, small-scale phonon mode calculations are difficult to impossible. We therefore utilize high-performance computing resources to conduct these simulations, the results of which provide essential insights for designing more efficient photovoltaic systems with silicon clathrates in the future, and contribute to advancements in our understanding of experimental measurements and results.

#14 Interfacial Activity Of Crude Oil Natural Surfactants

Author(s): Julia Cacciavillani, Junior, Chemical and Biological Engineering
Mentor(s): Jose Delgado-Linares, Carolyn Koh

Formation of stable water-in-crude (W/O) emulsions represent a major drawback in oil production. The occurrence of this type of dispersion generates several operational problems such as oil viscosification, sludge formation and corrosion of pipes and separation equipment. The stabilization of these W/O emulsions depends greatly on the interfacial activity of crude oil natural surfactants, which are heavy molecules (e.g., resins and asphaltenes) with polar functional groups linked to their hydrocarbon structure. The surfactant interfacial activity can be determined by interfacial tension (IFT) measurements of water-oil-surfactant systems; the lower the IFT, the higher the surfactant interfacial activity. In this work, a pendant drop tensiometer was used to measure the IFT of several crude oil – water systems and thus evaluating the interfacial activity of the oil phase. Likewise, the effect of several commercial flow assurance chemicals (e.g., corrosion inhibitor, scale inhibitor, asphaltene inhibitor) on IFT was determined. IFT results were qualitatively correlated with the stability of W/O emulsions.

#15 Characterization of Transition Metal Catalysts and Membrane Morphology in a Water Electrolysis Device

Author(s): Liam Carroll, First Year, Chemistry; Marco Salgado, Sophomore, Chemical and Biological Engineering
Mentor(s): Andrew Herring

Recent developments in electrochemical systems for green hydrogen production have seen more focus on utilizing non-platinum group metals as catalysts to lower operating costs. In this paper, we employed first-row transition metals as electrocatalysts for the oxygen evolution reaction of a water electrolysis device. Manganese (IV) oxide, manganese (III) oxide, and cobalt (II,III) oxide were selected due to each having some desirable balance of low overpotential and high catalytic activity. Catalyst performance after 100 hours of operation was observed and recorded, and characterization post-operation was performed. Over the 100-hour span, resistance measured in all cells decreased – ranging from 0.47 - 0.69 Ω cm2 at the beginning of tests to 0.33 - 0.56 Ω cm2 at the end of tests. Tafel slope analysis showed increased kinetic performance of manganese (IV) oxide (85±3 to 75±1 mV/dec) and cobalt (II,III) oxide (128±4 to 81±1 mV/dec) but decreased kinetic performance for manganese (III) oxide (137±44 to 113±2 mV/dec). Finally, FTIR mapping showed micrometer-sized changes in morphology in membrane structure corresponding to electrode templating.

#16 Bioinstructive Polymer Brush to Promote Signaling Cell Proliferation

Author(s): Caitlyn Castellion, First Year, Chemistry
Mentor(s): Ramya Kumar, Claire Nelson

Due to their ability to secrete molecules that address autoimmune disorders, cardiovascular diseases, or cancer, human mesenchymal signaling cells (hMSCs) have emerged as powerful cellular therapeutics. To augment hMSC secretory activity, hMSCs need to be genetically modified using therapeutic nucleic acids. Although engineered viral vectors can modify hMSCs efficiently and safely, viral gene delivery is expensive at scale. Non-viral vectors such as polymers are scalable and affordable but adversely affect hMSC viability and multipotency. To overcome bottlenecks in polymer-mediated DNA delivery to hMSCs, we will develop bioinstructive cell culture substrates that promote hMSC proliferation. Specifically, we will synthesize glycosaminoglycan-mimetic polymer brushes that can sequester and stabilize growth factors promoting hMSC proliferation. We will encode hydrophobic interactions into polymer brushes because cell adhesion is favored on moderately hydrophobic substrates. We will test whether the degree of sulfation and the incorporation of hydrogen bonding functional groups enhance growth factor binding and hMSCs proliferation. To test these hypotheses, we employ combinatorial polymer brush synthesis to systematically vary the incorporation of sulfonated, hydrophobic, and hydrogen bonding monomers in ternary and binary copolymer brushes. Polymer brushes were characterized using Fourier-transformed infrared spectroscopy (FTIR) to estimate copolymer composition and sulfation degree, ellipsometry to measure brush thickness, and contact angle goniometry to compare hydrophobicity. Future work will evaluate the capacity of glycosaminoglycan-mimetic brushes to support hMSC self-renewal and bind growth factors such as basic fibroblast growth factor.

#17(O) Exploring the Effects of Surfactants in Crude Oil on Gas Hydrate/Pipe Wall Interactions

Author(s): Bella Chase, Junior, Chemical and Biological Engineering
Mentor(s): Carolyn Koh, Christopher Brock

Gas hydrates are ice-like solids that form when a small, nonpolar gas such as methane/CO2 is trapped within a crystalline structure of water molecules under conditions of low temperature and high pressure, often forming in subsea oil pipelines. Remediating hydrate plugs in these pipelines requires understanding hydrate/pipe interactions. Mechanical shear push off measurements were conducted to determine the force necessary to remove a hydrate plug formed with water containing surfactants from various crude oils from inside carbon steel piping, in order to gain a better understanding of how hydrates stick to the inner pipe wall.

#18 Optically Driven Nanostructuring of Alloyed Metal Plasmonic Nanocrystals for Next-Generation Computing

Author(s): Cade Colston, Senior, Physics
Mentor(s): Matthew Crane

Metallic nanoparticles exhibit localized surface plasmon resonances (LSPR), which are resonant oscillations of free carriers in the nanoparticle when they are irradiated by light. This LSPR results in enhanced local electric fields, changes in the scattering of light, and enhanced absorption of light at the plasmon resonant frequency. This leads to uses in catalysis, spectroscopy, sensing, and more. The LSPR properties are highly dependent on the size, shape, composition, and arrangement of plasmonic nanoparticles. By altering these characteristics of the nanoparticles, the LSPR properties can be tailored to a desired application. Controlling the size, shape, and composition is well understood, however it is a challenge to control nanoparticle arrangement and placement with high precision. Here, we focus on controlling the arrangement of nanoparticles and aim to establish a method for synthesizing gold nanoparticle dimers using light and light induced plasmonic effects. The first step towards tailor made nanostructures is the targeted formation of nanoparticle dimers. Dimers are the simplest complex nanostructure, consisting of only two individual nanoparticles. Creating a process to synthesize these will give valuable insight towards creating more complex nanostructures. We explore how light, chemistry, and plasmonic irradiance can direct nanoparticle dimer formation.

#19 Decoupling Crop Production From Photosynthesis

Author(s): Aidan Cooper, Senior, Chemical and Biological Engineering
Mentor(s): Nanette Boyle

With the decreasing amount of available and arable land on earth, advancements in agriculture must be made to keep up with the food demands of a growing population. One potential advancement is to increase crop yields by making photosynthesis more efficient. A clever way of achieving this mimics photosynthesis by artificially fixating CO2 from the atmosphere into acetate, a feedstock for many organisms. By electrolyzing CO2 and H2O in a solar-powered electrochemical reactor, atmospheric carbon can be converted into acetate, a feedstock for many organisms including plants, at an efficiency much higher than photosynthesis can achieve. Feeding plants acetate whilst limiting photosynthetic products is the next step in proving the viability of this technology. The research being done on the metabolism of Arabidopsis thanalia in different modes of light exposure can provide important data to compare against a genetically modified variant that expresses more of the enzyme isocitrate lyase, which allows for the increased metabolism of carbon through the glyoxylate cycle, conserving carbon through the citric acid cycle and allowing for the use of acetate as a carbon source for biomass instead of CO2 via photosynthesis.

#20 Fluid Mechanics of Biomass and Biomaterials

Author(s): Lauren Crain, Junior, Quantitative Biosciences and Engineering
Mentor(s): Joseph Samaniuk, Jess Troxler

Efforts to enhance carbon-neutral fuel sources have intensified due to climate change concerns, including efforts to convert lignocellulosic biomass to sustainable aviation fuel. Biofuels derived from biomass hold potential to significantly contribute to energy needs. Currently fuels produced from lignocellulosic biomass accounts for less than 5% of fuel consumption in the US, but in theory it could reach as high as 30% given available biomass resources. This research explores steps leading up to biofuel production from corn stover, focusing on different lengths of enzymatic hydrolysis applied to the slurries as well as different percent viscosities. Using custom 3D printed geometry that would prevent wall-slip and ejection, measurements were made on the Discovery Hybrid Rheometer 3 at 20oC and 50 oC. After calibrations, a fractal vane was used for slurries with high viscosity to prevent errors due to the larger sized fibers that would create inaccurate data, for lower viscosity measurements cross hatch parallel plates were used. For later processing of the biomass, pressure drop calculations were made to aid in process design. Pressure drop calculations are challenging because enzymatically hydrolyzed slurries are shear thinning fluids; consequently, one cannot use a single viscosity to make the calculations, and an appropriate non-Newtonian constitutive model is required. Multiple flow rates and pipe diameters were considered in the pressure drop calculations, and an optimal design discussed. Yield stress, which was determined using the Herschel Bulkley model, as well as pressure drops were measured to influence design and operating parameters of enzymatic hydrolysis reactors.

#21 Synthesis and Characterization of Gradient Copolymers for Synthetic Gene Delivery Systems

Author(s): Jordan Estridge, Senior, Chemical and Biological Engineering
Mentor(s): Jessica Lawson, Ramya Kumar

In lieu of viral vectors for genetic therapeutics, synthetic copolymers of cationic (DIP and DMA) and hydrophilic (HEMA) monomers have emerged to improve transfection, reduce cellular toxicity, and promote stability of the complexed DNA-polymer polyplexes. These properties are highly dependent on the polymer microstructure, yet current research has focused primarily on statistical and block copolymers, lacking exploration into the efficacy of gradient copolymers. To predict the arrangement of cationic monomers in the statistical and gradient copolymers, we determined the reactivity ratios of the monomers. Eight copolymers were synthesized with varying cationic-hydrophilic monomer ratios and analyzed for polymer composition via 1H-NMR. Plotting the final polymer compositions versus the input monomer ratios, we found rDIP = 1.45 and rHEMA = 1.13 in the DIP-HEMA copolymerization and rDMA = 0.09 and rHEMA = 0.47 for the DMA-HEMA copolymerization. These results revealed the DIP-HEMA copolymer adds monomer randomly while the DMA-HEMA copolymer adds monomer in a more alternating pattern. Furthermore, to determine which polymer architectures would be suitable for gene delivery, aggregation analysis of the polyplexes in serum was conducted. The statistical architecture had the highest aggregation, the block architecture had little aggregation and the gradient architectures had intermediate aggregation. Ultimately, we found polymer architecture has a significant role in polyplex stability and can have further implications in cellular transfection and toxicity. Further research on the impact of polymer microstructures on polyplex characteristics such as transfection, toxicity, and stability can allow us to optimize synthetic gene delivery.

#22 Silicon Clathrates in Photovoltaics Solar Cells

Author(s): Audrey Faricy, Junior, Physics
Mentor(s): Carolyn Koh, Reuben Collins

This project aims to understand and characterize crystalline allotropes of silicon, alternative crystal structures to diamond silicon. Doped Si-allotrope thin films hold promise of exciting optical and electronic properties. They are also promising for future integration into quantum information science (QIS) devices and photovoltaic cells. Using a combination of photolithography, reactive ion-etching, Raman spectroscopy, and focused ion beam-induced deposition, efforts are being pursued to characterize single grains of these materials.

#23 Mini Winnies: Scaled Down Winogradsky Columns for Microscopy in Microbiology Education

Author(s): Mara Fink, Senior, Chemical and Biological Engineering
Mentor(s): Kevin Cash, Tyler Sodia

Soil is full of microbial communities that break down and recycle nutrients and foreign chemicals. These microbes are interdependent on one another, but it is currently very hard to gain an in-depth understanding of how these microbes interact. Using a model ecosystem like Winogradsky columns, invented by Sergei Winogradsky in the 1880s, have commonly been used as a microbiology classroom learning tool in K-12 and collegiate education can help to explore these complex interactions. However, they can be challenging to examine with microscopy. To overcome this barrier, we scaled down Winogradsky columns into NMR tubes and replaced the natural sediment with a transparent soil substitute with the goal of observing the microbial growth under bright field microscopy without column disassembly. Using this “Mini Winnie” approach, students can practice their microscopy skills while observing microbial growth inside the column after only days of incubation on the laboratory windowsill. Overall, we believe that the Mini Winnies provide a simple method for maximizing student engagement while giving them a greater understanding of how microorganisms interact in the environment. The next steps for this project are to introduce fluorescent nanosensors to Mini Winnies to determine how metabolite concentrations change when moving deeper into the system.

#24 Impacts of Static Magnetic Fields on P. polycephalum Foraging Behavior

Author(s): Kyra Frank, Junior, Quantitative Biosciences and Engineering
Mentor(s): Suzannah Beeler, Kevin Cash, Tyler Sodia

Slime molds, despite their simplicity as single cellular organisms, exhibit remarkable behavior in navigating their environments and locating food sources. This research project aims to investigate the impact of static magnetic fields on the foraging behavior of Physarum polycephalum, specifically examining whether the presence of a static magnetic field deters them from accessing food sources. The experimental setup involves cultivating slime molds in controlled environments with food sources placed in the presence or absence of a magnetic field. The behavior of slime molds towards these food sources will be observed and analyzed using time-lapse imaging. By varying orientation of the magnetic field, we aim to discern any correlation between magnetic fields and slime mold foraging behavior. This research holds significance in both fundamental understanding and practical applications. Understanding how slime molds respond to magnetic fields can provide insights into their sensory mechanisms and navigational strategies. Furthermore, elucidating the deterrence effect of magnetic fields on slime molds could have implications in computation and biotechnology, where controlling the movement of organisms is desirable.

#25 Investigating the Potential of Phytohormones to Increase Lipid Production in Microalgae for Biofuels Production

Author(s): Andy Gebhardt, Senior, Quantitative Biosciences and Engineering
Mentor(s): Nanette Boyle, Michelle Meagher

Phytohormones play crucial roles in mediating algal-microbe interactions within the phycosphere, the region surrounding algal cells. Among these phytohormones, salicylic acid (SA) and 2,4 dichlorophenoxyacetic acid (2,4-D) have been shown to influence physiological processes in plants and algae including defense responses and growth regulations. However, their overall role on algal lipid production and synthesis remains less understood. In this study, we investigated the effects of SA and 2,4-D on algal growth and its lipid production to potentially increase biofuel production downstream at a larger scale. We hypothesized that given the importance of phytohormones in defense and cell growth that SA and 2,4-D would increase lipid production and synthesis due to hormones coming from the phycosphere. To test this hypothesis, three algal culture strains were treated with SA and 2,4-D and their growth dynamics monitored over time to produce a growth curve. These cultures were then processed, and their lipid and protein contents measured to determine changes based on the phytohormone influence. Our results revealed partial support to the hypothesis with alterations in overall cell growth, lipid composition, and protein concentration. Interestingly, the cultures did not all perform the same way under the different growth conditions and exhibited changes that are not clearly understood. Due to this, further studies are needed to understand the modulation caused by phytohormones and how different concentrations play a role in lipid production pathways in microalgae.

#26 Designing Catalysts for Efficient Aromatic Alkylation: Integrating Microporous Environments into Mesoporous Structures

Author(s): Breanna Hayes, Senior, Chemical and Biological Engineering
Mentor(s): Stephanie Kwon

Aromatic alkylation with alkenes and alkanols is a fundamental reaction in the chemical industry, enabling the synthesis of essential chemical intermediates such as xylene, ethylbenzene, ethyltoluene, and cumene. Despite the efficiency and sustainability achieved by employing zeolitic materials at low temperatures, challenges persist due to competing reactions like dimerization, oligomerization, and disproportional reactions. Moreover, zeolites encounter mass transport limitations in the microporous environment, especially for bulkier alkylated products, hindering their efficacy. This study aims to overcome these challenges by developing catalysts for toluene (C_7H_8) alkylation with ethylene (C_2H_4), with a focus on generating monoalkylated para-ethyltoluene (p-C_9H_{12}) isomers, crucial intermediates in the production of p-methylstyrene (p-MS), an excellent alternative to styrene monomer. Our approach involves integrating a microporous environment into the 2.5 nm mesoporous

structure of Al-MCM-41, which utilizes acid-catalyzed active sites similar to zeolites. The synthesis process involves attaching grafting molecules of kinetic diameter ranging from ~0.55-0.65 nm onto the active sites of Al-MCM-41, followed by depositing silica oxide (SiO2) around the grafting molecules, thus shielding the active sites. The thickness of SiO2 deposition onto Al-MCM-41 is controlled by the amount of tetraethyl orthosilicate, a precursor for SiO2 deposition, added during the synthesis process. Removal of grafting molecules via an oxidation process creates the desired microporous environment. BET measurements and N2 physisorption are employed to quantify the pore size distributions of the catalyst. Overall, this research aims to significantly enhance the scientific community's understanding of optimal microenvironments for alkylation processes, particularly focusing on stability and isomer selectivity.

#27 Characterization of a Drug Delivery Nanocapsule Targeted to the Pancreatic β-Cell for Preservation in Type 1 Diabetes

Author(s): Julianna Hays, Senior, Quantitative Biosciences and Engineering
Mentor(s): Nikki Farnsworth, Jillian Collins

Type 1 Diabetes (T1D) results from autoimmune destruction of pancreatic β-cells, leading to insulin deficiency and metabolic dysregulation. Current therapies including insulin injection and islet transplantation are non-ideal long-term solutions as they do not stop disease progression, and current therapies designed to preserve or proliferate β-cells in T1D suffer from low efficacy and off-target effects. This study proposes a novel β-cell targeted approach to deliver therapeutic cargo directly to pancreatic β-cells to increase therapeutic efficacy and reduce off-target effects. Our previous research identified the hydrophilic peptide δV1-1 as protective against β-cell death. Therefore, we developed cationic polymeric nanocapsules (NCs) encapsulating δV1-1 that are coated with one of two β-cell targeting moieties: (1) hyaluronic acid conjugated to exendin-4 (HA-Ex4), an agonist of the glucagon-like peptide 1 receptor (GLP-1R) expressed on the β-cell surface; and (2) ectonucleoside triphosphate diphosphohydrolase 3 (ENTPD3), an antibody marker specific to mature human β-cells. We hypothesize that HA-Ex4 or ENTPD3-coated NCs will target β-cells more effectively than non-targeted NCs. In vitro studies demonstrate the NC's non-toxicity to islets and their ability to bind different β-cell specific moieties, enhancing β-cell specificity. In vivo studies in immunodeficient NOD-SCID mice reveal NC accumulation in the pancreas, with β-cell specific coating reducing off-target accumulation in other tissues. Finally, in vitro studies demonstrate NCs' capability to deliver δV1-1 to β-cells to prevent cell death. This research demonstrates the potential of targeted NCs in delivering therapeutic cargo to β-cells to mitigate β-cell loss in patients with T1D.

#28 Engineering Surface Properties Through Controlled Radical Polymerization for Therapeutic Application

Author(s): Wakana Kani, Junior, Chemical and Biological Engineering
Mentor(s): Ramya Kumar

Polymers play an integral role in therapeutic applications, especially in the development of drug delivery systems. Advancements in controlled polymerization have allowed for a greater control of polymer architecture. This work explores the atom transfer radical polymerization (ATRP) of hydrophobic polymers in alcohol-water media to find reaction conditions balancing an increased reaction rate while maintaining consistency and stability. The rate of polymerization was tuned by adjusting reactant ratios, altering the rate of radical formation and deactivation. Different solvent properties were studied as ATRP relies on water for a controlled reaction, necessitating a delicate balance with the alcohol required to solubilize the monomer. More protic solvents were shown to increase the reaction rate, but resulted in decreased control due to a higher probability of termination events. After successfully developing optimized reactions, the work is translated to polymerization on nanoparticles for drug delivery applications. The effects of pH and ion concentration on polymer swelling are studied through film characterization using dynamic light scattering (DLS) and zeta potential, measuring the changes in film thickness and surface charge.

#29 Screening for Mutants in Algal Cultures Grown in Diel Light

Author(s): Emma Khorunzhy, Senior, Chemical and Biological Engineering
Mentor(s): Nanette Boyle

With the ongoing threat of climate change, algal biofuels have caught the scientific community's attention, and algae mutants are screened for their lipid production or growth rate. Currently, one area for improvement is that most algal research groups screen for mutants in cultures grown in continuous light; however, this screening process can ignore mutants that show a specific phenotype in diel light. Three strains of the mixotrophic algae Chlamydomonas reinhardtii, CC5325 (WT), and two strains from the CLiP library, LMJRY0402095682 (ECH2 MT) and LMJRY040211250 (ATO1 MT), were grown in TAP media and subjected to diel light conditions. Once the cultures reached the mid-exponential phase of their growth curve (OD ≥ 0.4), the cultures were harvested, and DNA and RNA were extracted. The CIB1 insertional mutagenesis cassette was verified using PCR, and the samples were run in a 1% gel electrophoresis because the CLiP mutant library reported only 70% probability that the strains were mutants. The PCR targeted the CIB1 cassette and the RAK1 and PSAD control genes. Results found that the ECH2 and ATO1 mutant strains expressed the CIB1 cassette. RT PCR further showed these mutants are knockdowns rather than knockouts because the cells express mRNA for the ATO1 and ECH2 genes, albeit at a lower level than the CC5325 wildtype strain. Future work includes characterizing these mutants' biomass composition and further using diel light conditions to screen for other CLiP library strains. This project highlights the importance of screening algae grown in diel light to uncover possible unseen phenotypes.

#30 Nanoscale Engineering of Porous Membrane Supports

Author(s): Kagan Killough, Junior, Chemical and Biological Engineering
Mentor(s): Colin Wolden, Douglas Way

Catalytic membrane reformers (CMRs) are an emerging reactor technology capable of intensifying chemical production and separation. One application of this technology is producing hydrogen for fuel. Storing pure hydrogen is challenging, but hydrogen is easily stored chemically within a liquid carrier like ammonia. However, re-forming carrier-stored hydrogen currently employs a packed bed reactor and subsequent separation: energy-intensive processes. We have developed a CMR that combines the steps of hydrogen reforming by employing a thin, hydrogen-selective palladium membrane plated onto a porous, catalyst-impregnated ceramic support. The removal of reformed hydrogen through the membrane favors hydrogen production thermodynamically and kinetically. Accordingly, improving hydrogen flux through the CMR becomes paramount in improving productivity. Previous experiments revealed that hydrogen permeance is presently limited by the resistance through the ceramic support. Namely, this resistance is caused by a ~25-micron-thick mesoporous layer coating the macroporous bulk of the commercially-available supports used for the project. This work aims to engineer supports with a surface geometry facilitating a defect-free membrane, yet improving flux by minimizing the mesoporous layer. This will be achieved through modification of symmetric macroporous supports via exposure-limited atomic layer deposition (ALD). In this work, we developed exposure-limited ALD recipes for zirconia and alumina. This technique provides nanoscale engineering of symmetric supports to reduce external pore size without compromising permeance, finding pore diameters could be closed off by 60% before significantly impacting permeance. Future work will employ scanning electron microscopy to quantity depth of ALD penetration and further refinement of ALD parameters to enhance CMR performance.

#31 Understanding Growth Rates Under Different Light Conditions in Three Strains of Chlamydomonas reinhardtii

Author(s): Valeria Marchitto, First Year, Chemical and Biological Engineering
Mentor(s): Sandra Gomez Romero, Nanette Boyle

Currently, algae research groups cultivate and screen their algae strains in continuous rather than diel light. We hypothesized that some mutants may show a distinct phenotype in diel light. To test this hypothesis, we grew three Chlamydomonas reinhardtii strains, the wildtype strain CC-5325 and the mutant strains LMJRY040211250 (ATO1 mutant) and LMJRY0402095682 (ECH2 mutant). The mutants were identified by computer simulations to have higher lipid productivities in diurnal light. These strains were grown in flasks under two different conditions, continuous light, and diel light, to measure the growth rates of these strains. We took daily samples and measured the cell concentrations by measuring the optical density (OD) with a spectrophotometer. We used these measurements to construct growth curves and calculate the growth rates of these algae strains. Our results show that the mutant strain grew faster under both conditions than the CC-5325 strain, and both strains grew faster in continuous light. Specifically, the ATO1 mutant strain had a 37% increase in growth rate in diel light compared to the wildtype strain, and it had a 25% increase in growth rate in continuous light compared to the wildtype strain. Future research includes characterizing the growth curve and growth rates of additional mutants. Our research highlights the importance of cultivating and screening algae in diel light to uncover unseen phenotypes.

#32(O) The Role of Extracellular Matrix Stiffness in Modulating Ca2+ Dynamics and Insulin Secretion in Mouse Islets

Author(s): Stephanie Morrall, Senior, Quantitative Biosciences and Engineering
Mentor(s): Chelsea Johansen, Nikki Farnsworth

The pancreatic islet extracellular matrix (ECM) scaffolds the cellular architecture and regulates insulin secretion and β-cell survival through biochemical and mechanical signaling. The ECM interacts with β-cells via integrins, responds to glucose levels, and protects β-cells from immune attack. Our work aims to examine the effect of ECM stiffness on insulin secretion in mouse islets, focusing on the modulation of intercellular Ca2+ signaling pathways. We hypothesize stiffer matrices enhance β-cell glucose sensitivity and alter Ca2+ dynamics through activation of the mechanosensitive Piezo1 channel. Confocal microscopy imaging of Ca2+ signaling was used to determine if Piezo1 plays a role in insulin secretion dysfunction in mouse islets. Since intracellular Ca2+ triggers the exocytosis of insulin granules from β-cells, we observed Ca2+ response to glucose stimuli of islets embedded in varying weight percentages of reverse thermal gel (RTG) scaffolds. Additionally, ELISA was used to directly measure insulin secretion. RTG mimicked in vivo mechanical at variable matrix stiffnesses without compromising the structural integrity or viability of the islets. Our results show that increased matrix stiffness leads to islet dysfunction. Increased Piezo1 activation caused alterations in calcium signaling dynamics including a reduction in first-phase area under the curve following a glucose stimulus. This corresponded with reductions in insulin secretion, confirming islet dysfunction. The Piezo1 inhibitor GsMTx-4 restored normal islet functionality, confirming Piezo1's role. Therefore, targeting ECM properties and Piezo1 activity could serve as potential therapeutic strategies for restoring islet functionality in conditions such as type 2 diabetes and pancreatic cancer.

#33(O) Cell Culture Substrates Functionalized with Glycosaminoglycan-Mimetic Polymer Brushes to Augment Human Mesenchymal Stem Cell Self-Renewal

Author(s): Claire Nelson, Senior, Chemistry
Mentor(s): Ramya Kumar

Human mesenchymal stem cells (hMSCs) are promising cellular therapeutics because of their ability to secrete factors that rescue diseased cells. Genetic modification of hMSCs is essential to augment their therapeutic activity, but non-viral genetic delivery approaches are expensive and inefficient. To overcome these current barriers, we propose to prime hMSCs on bioactive cell culture substrates that promote hMSC self-renewal. Glycosaminoglycans (GAGs) are carboxylated and sulfonated polysaccharides that can sequester growth factors responsible for enhancing hMSC self-renewal. Using GAGs as inspiration, binary and ternary statistical copolymer brushes with varying compositions using 2-hydroxyethyl methacrylate (HEMA) to provide hydrogen bonding, 2-methoxyethyl methacrylate (MEMA) to increase the hydrophobicity required for cell adhesion, and 3-sulfopropyl methacrylate (SPMA) to vary the electrostatic binding of growth factors were designed. The substrates were chemically characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Photoelectron Spectroscopy (XPS), ellipsometry, and contact angle. Bioactivity was determined by using

Enzyme Linked Immunosorbent Assays (ELISAs) to measure the
adsorption of growth factors. We predict that substrates with a moderate degree of hydrophobicity and sulfonation will provide the right balance to maximize bioactivity and hMSC self-renewal. Future work consists of more faithfully mimicking the structure of GAGs by synthesizing methacrylate polymers that incorporate glycan residues to improve the biological fidelity of these coatings.

#34 Molecular-Templated Sio2 Deposition Methods For Creation Of Microporous Layers On Bulk Oxides

Author(s): William Pham, Senior, Chemical and Biological Engineering
Mentor(s): Stephanie Kwon, Kay Ithisuphalap, Manasi Vyas

Bulk metal oxides are prevalent in industrially relevant heterogeneous catalytic reactions, such as selective oxidation, aldol condensation, and photocatalysis. In particular, titanium dioxide (TiO2) has garnered attention for its high reactivity for aldol condensation reactions. Despite its high reactivity, TiO2 exhibits low selectivities. Previous studies showed that confinement effects (i.e., confining reactions within pores) created by controlling the cavity size of zeolites improved product selectivity. In this work, we aimed to induce confinement effects to promote product selectivity of acetone aldol condensation by tailoring microporous silicon dioxide (SiO2) environments around anatase TiO2 active sites. The synthesis of microporous SiO2/TiO2 catalysts involved template grafting onto TiO2, SiO2 deposition around the grafted templating molecules, and template molecule removal to create pores. Pyrocatechol emerged as a promising candidate for grafting. SiO2 was deposited around the grafted catechol molecules to form a barrier around the pores, which were created by successively removing catechol through oxidative treatments. Transmission electron microscopy (TEM) analysis confirmed uniform SiO2 coverage around TiO2 with quantifiable thicknesses that were linearly related to the amount of tetraethyl orthosilicate (TEOS) precursor used. BET analysis revealed that the micropore surface areas and volumes increased with the amount of TEOS used, showing improved micropore definition with increasing SiO2 deposition. Furthermore, NLDFT analysis suggested that these pores had an average diameter of ~0.6 nm, reflecting the kinetic diameter of catechol (~0.55 nm). Demonstration of controlled synthesis of TiO2 with confinement geometries may provide a gateway into controlling product selectivities of aldol condensation reactions.

#35(O) Changes in Extracellular Matrix Stiffness Mediate Pancreatic Islet Function: Insights Into Glucose Metabolism And Mitochondrial Dynamics

Author(s): Amit Sela, Junior, Quantitative Biosciences and Engineering
Mentor(s): Nikki Farnsworth, Chelsea Johansen

In the pancreas, the islet is surrounded by a protein scaffold called the extracellular matrix (ECM) which regulates cell survival and insulin secretion. Little is known about how mechanical properties of the ECM, like matrix stiffness, regulate islet function in health and disease. Previous research conducted on islets from a rat model of type 2 diabetes (T2D), marked by increased ECM stiffness and islet dysfunction, revealed increased 6-phosphofructo-

2-kinase/fructose-2,6-bisphosphatase 3 (PFKFB3) levels and
mitochondrial fragmentation. Mitochondrial morphology is regulated by the membrane potential (ΔΨ), with alterations in ΔΨ influencing fusion-fission dynamics crucial for maintaining mitochondrial function. The mechanisms underlying the mechanotransduction regulation of glucose metabolism and mitochondrial dynamics have not been well studied in intact islets. We hypothesize that increasing matrix stiffness will yield a depolarized ΔΨ and an increase in mitochondrial fragmentation. To test our hypothesis, mouse and human cadaveric islets were encapsulated in a 3D, RGD-functionalized PEG hydrogel to mimic the islet microenvironment to physiologically relevant stiffnesses that are seen in T2D ECM. Our results indicate that increased scaffold stiffness causes insulin secretion dysfunction mediated by increases in phosphofructokinase (PFK) activity, which is a key regulatory step in glycolysis, and the depolarization of the ΔΨ. Our results emphasize the role that ECM stiffness plays in regulating function. It also supports further investigation into the modulation of glucose metabolism and mitochondrial dynamics to restore islet function in diseases like T2D where fibrosis of the peri-islet ECM leads to increased tissue stiffness and islet dysfunction.

#36 Cationic Copolymer Architecture Impacts Serum Stability for Gene Delivery

Author(s): Grant Wheeler, Sophomore, Quantitative Biosciences and Engineering
Mentor(s): Jessica Lawson

Cationic polymers have emerged as a popular alternative to viral vectors for gene delivery due to their cost-effectiveness, risk mitigation and overall practicality. Current research has focused on block and statistical copolymers, in which cationic monomers are polymerized with hydrophilic monomers. The copolymers form polyplexes when the cationic monomers bind with anionic plasmid DNA (pDNA) and are shielded from biological environments by the hydrophilic monomers. However, the impact of polymer microstructure on serum stability, nucleic acid loading and cellular toxicity remains underexplored. We synthesized block and statistical copolymers along with three gradient copolymers with varied cationic monomer distributions to understand how the polymeric microstructure impacted the polyplex properties. In introducing the polyplexes to serum, we found the block did not aggregate significantly, the statistical aggregated, but the gradients varied between the two. Furthermore, we created Zimm plots using static light scattering to determine the molar mass and size of the polyplexes. The molar mass of the polyplexes was further used to determine the number of pDNA copies in each polyplex. The block had the highest pDNA loading followed by the gradients and the statistical. The gradients and statistical outperformed the block for cellular transfection, while the block exhibited the lowest cellular toxicity. Evidently, the stability, pDNA loading and toxicity of polyplexes are highly dependent on the polymer microstructure. By understanding more about the distribution of cationic monomers within polymers, we can optimize gene delivery vectors to improve stability in biological environments and reduce cellular toxicity.

#37 Mixed Micelleplexes: Optimization and co assembly of block and statistical co-polymers enhances cell viability, and plasmid DNA delivery

Author(s): Jillian Yanes, Junior, Chemical and Biological Engineering
Mentor(s): Ramya Kumar, Ram Prasad

Gene therapy has proven enormous therapeutic promise for inherited disorders as well as highly prevalent diseases like cancer, diabetes, and age-related macular degeneration. Cationic polymers have been studied extensively to mediate efficient gene delivery into target cells due to their ready availability, low cost, and ability to condense bulky anionic payloads like plasmids (pDNA). However, the toxicity of the polymers and their interactions with serum proteins limit their therapeutic applicability. We hypothesized that mixed micelles, co-assembly of block (B) copolymers with statistical (S) /gradient(G)copolymers, will outperform conventional micelles as well as linear polymers in maintaining colloidal stability, promoting efficient pDNA delivery, and minimizing toxicity. Block copolymers were co-assembled with either gradient or statistical copolymers using different mixing ratios (B/G and B/S) to form mixed micelles, which were then complexed with pDNA via electrostatic interactions, forming mixed micelleplexes. We compared the toxicity and pDNA delivery efficiency as a function of B/G and B/S mixing ratios using HEK 293T cells. Particle size analysis demonstrated that all mixed micelleplexes were sized between 100 to 200 nm, which favors high cellular uptake. Mixed micelleplexes were less toxic than polyplexes and conventional micelleplexes. Mixed micelleplexes formed from block and statistical copolymers performed best among all the combinations tested. Our research findings paved the way for rationally co-assembling copolymers with different monomer spatial distributions (block/gradient/statistical) into mixed micelleplexes that outperform traditional micelles in terms of gene delivery.

CHEMISTRY

#38 X-ray Photoelectron Spectroscopy Analysis of Degradation in Polymer Electrolyte Membrane Fuel Cell Catalyst Layers

Author(s): Dylan Kuiken, First Year, Chemistry
Mentor(s): Svitlana Pylypenko, Jayson Foster

X-ray Photoelectron Spectroscopy (XPS) is a surface analysis technique that uses the photoelectron effect to characterize and identify a materials elemental composition and chemical state in the top 3-10nm of the material. XPS is a vital tool for research in polymer electrolyte membrane fuel cells (PEMFCs) due to its ability to provide elemental and chemical speciation of the main components of the catalyst layer (CL), including catalyst, support and ionomer. Analysis of the CL is paramount due to the necessity of a highly efficient and long-lasting CL to make PEMFCs economically viable. Within this project, eight total CL samples were analyzed via XPS to study the effects of degradation on the composition of the CL. The first subset of samples included CLs made with Pt catalysts supported on carbon support (Pt/C), while the second subset of samples consisted of CLs fabricated with carbon supported bimetallic PtCo. Composition of samples degraded under different durability testing protocols were compared to the composition of the respective catalyst layer before testing. This project will showcase how XPS can be used to study surface level changes of the CL due to degradation through spectra analysis and elemental peak ratio comparisons. Analysis of the CLs with XPS provides complimentary information to electrochemical testing and electron microscopy characterization. A multi-technique approach is paramount for improving understanding of degradation and enabling further improvements of CLs and PEMFCs performance and long-term durability.

#39 Investigating the inhibition of the SUF-like pathway in S. *aureus* and B. *subtilis*

Author(s): Katelyn Aasman, Sophomore, Chemical and Biological Engineering
Mentor(s): Richard Holz, Emily Sabo

Fe-S clusters are essential to the biological function of many organisms, including the Gram-positive bacteria *Staphylococcus aureus* and *Bacillus subtilis*. Formation of Fe-S clusters in the nonredundant biosynthetic sulfur mobilization (SUF)-like pathway utilizes essential proteins, SufS and SufU, to capture and transport S to form Fe-S clusters on the scaffold protein complex, SufBCD. Inhibition of any protein in the SUF-like pathway should prevent the formation of Fe-S clusters and result in cell death. Given that the SUF-like pathway is not found in humans, proteins in the SUF-like pathway are ideal antibiotic targets. SufU's zinc-containing active site makes it a potential target of compounds containing zinc binding groups (ZBGs). These ZBGs could bind SufU's active site, inhibit activity, and block the pathway. However, *S. aureus* SufU (*Sa*SufU) kinetic constants have not yet been published, providing an obstacle to investigating *Sa*SufU inhibitors. Since *B. subtilis* SufU (*Bs*SufU) kinetic constants have been published, an avenue exists to perform inhibition studies on SufU in the *B. subtilis* system. This work aims to perform inhibition studies of *Bs*SufU. Because of the homology between *Sa*SufU and *Bs*SufU, identifying inhibitors of *Bs*SufU will provide a viable path for investigating *Sa*SufU inhibition and allow for the development of *S. aureus* targeted therapeutics.

#40 A Bottom-Up Approach to Defining the Critical Variables of Zirconia and Sulfated Zirconia Heterogeneous Catalyst Synthesis

Author(s): Runeem Al-Abssi, Junior, Quantitative Biosciences and Engineering
Mentor(s): Michael McGuirk, Scott Cleary

Sulfated zirconia (SZrO) is a highly active superacid catalyst that is more efficient at cracking C–C bonds, such as those in the backbone of polyolefins, than 100% sulfuric acid. Despite its industrial importance, the mechanisms governing SZrO's catalytic activity, particularly in alkane activation, are poorly understood. This lack of comprehension is due to SZrO's sensitivity to synthesis conditions, which causes variations in acidity and catalytic potential. Minor alterations in synthesis can yield SZrO forms exhibiting varying degrees of acidity, some significantly stronger than Brønsted superacidity thresholds. These stronger forms have an unusually high number of strong Brønsted and Lewis acid sites, which are thought to allow for efficient alkane activation via cooperative Brønsted–Lewis pair activity. However, ambiguity in the field on how to synthesize SZrO reliably in its most active form continues to hamper its utility and application. Therefore, this research focuses on determining the impact of synthetic parameters such as zirconium hydroxide precursor kinetics (e.g., base addition rate, pH, anion abundance) and strategies for controlling zirconia formation before sulfation (e.g., particle size, calcination). Understanding these variables is critical for controlling

crystal phase, surface area, and acidity, thereby optimizing SZrO's catalytic performance. By comprehensively investigating these synthetic parameters, we aim to understand SZrO's active sites and the source of its superacid-like activity. This understanding will facilitate the design of syntheses aimed at enhancing the strength and abundance of catalytically valuable active sites, thereby improving SZrO's industrial applications and other solid superacids.

#41 Synthesis of Organic Glasses Used in Nuclear Materials Detection

Author(s): Grant Bell, Senior, Quantitative Biosciences and Engineering
Mentor(s): Alan Sellinger

The detection of special nuclear materials (SNMs) at borders and ports remains a critical imperative for safeguarding national security and upholding global safety standards. Unfortunately, the prohibitive costs associated with current detection methods render comprehensive screening of trucks, trains, and ships impractical. Over the past half-century, organic plastics and crystals have been used to detect nuclear materials. Our research with organic glass scintillators (OGS), which emit light after interacting with ionizing radiation, offers a promising and innovative pathway for nuclear material detection. These OGS are comprised of both a fluorophore—a light-emitting aromatic compound—and a silane that are coupled through traditional carbon-carbon coupling using the Heck mechanism. The optical, thermal, and physical properties of the glass scintillators can be meticulously fine-tuned by altering the chemical composition of the fluorophore via alkylation and incorporating a variety of silanes. This tailoring of molecular compositions optimizes their sensitivity and responsiveness to ionizing radiation, positioning them as practical and compelling solutions for enhanced radiation detection capabilities. The added capability for distinguishing between neuron and gamma radiation through pulse shape discrimination (PSD) would be an improvement on current technology used in these applications.

#42 Optimizing Sustained Fragrance Release: A Novel Approach Using Mesoporous Silica Nanomaterials for the Discharge of Oxacycloheptadec-8-en-2-one

Author(s): Joseph Brock, First Year, Chemistry
Mentor(s): Brian Trewyn

Within the fragrance and perfumery industry, there is modern interest in novel methods of sustained release of fragrance, to control the release of odorant compounds over several hours. Since most of these molecules are highly volatile, their release rate is a significant factor to be considered. This research investigates the prolonged release of fragrance compounds from mesoporous silica nanomaterials, specifically focusing on MCM-41, a type of mesoporous silica nanoparticles (MSN). The study compares the release of oxacycloheptadec-8-en-2-one (AMB), a macrocyclic lactone fragrant compound known for its musky scent in a phosphate-buffered saline (PBS) solution, from the pores of mesoporous silica, post-loading in ethanol. The loading process of AMB into the mesoporous silica involves a meticulous procedure to ensure efficient and uniform loading. MCM-41 was selected for its ability to be further functionalized with different groups to optimize perfume real-world applications and due to the high loading capacity. The properties of AMB, such as its volatility, scent, and solubility, play a crucial role in its release behavior from the mesoporous silica. The research findings provide valuable insights into the controlled release of fragrance compounds, particularly in perfume applications, where prolonged and consistent fragrance release is desirable.

#43 Understanding Spatial Degradation of Polymer Electrolyte Membrane Fuel Cell Cathode Catalyst Layers using Particle Size Analysis

Author(s): Colin Butrico, First Year, Chemistry
Mentor(s): Svitlana Pylypenko, Matthew Coats

Polymer electrolyte membrane fuel cells (PEMFC) are a promising technology to power heavy-duty vehicles that currently rely on conventional combustion engines. The state-of-the-art catalysts for PEMFCs to catalyze the kinetically slow oxygen reduction reaction at the cathode are platinum-based nanoparticles on a carbon support (Pt/C). Concerns over durability due to degradation and the high cost of the catalyst propel a need to better understand the degradation mechanisms of the catalyst layer under PEMFC operating conditions.Transmission electron microscopy (TEM) has been widely used to investigate fuel cell catalyst layers in the membrane electrode assemblies (MEAs) and to determine the probable degradation mechanisms of PEMFCs by using nanoparticle size analysis comparing fresh and aged samples. Prior studies showed degradation is nonuniform throughout the catalyst layer and is spatially dependent based on the location within the cathode catalyst layer (CCL) thickness. In this project, sample location within the MEA was tracked, and TEM images were taken and analyzed from three distinctive regions including the gas diffusion layer catalyst layer interface (GDL-CL), middle of the catalyst layer (MID), and membrane catalyst layer interface (PEM-CL). These MEA cross-sections were prepared using ultramicrotomy. Nanoparticle analysis was then performed using ImageJ before being imported into MATLAB to fit the particle sizes using lognormal distributions. Analysis of aged samples relative to the initial untested MEA at similar locations provided a more complete comparison of degradation. Future work will employ a similar procedure to investigate MEA samples that were aged under various testing conditions.

#44 Investigation of Catalyst Degradation in Proton Exchange Membrane Fuel Cells using TEM and Particle Size Analysis

Author(s): Emma Carstens, Senior, Chemistry
Mentor(s): Svitlana Pylypenko, Matthew Coats

Proton exchange membrane fuel cells (PEMFCs) offer a promising way to decarbonize the automotive industry. However, catalyst degradation presents a significant challenge in the durability and performance of PEMFCs. This study investigated the degradation mechanisms affecting the platinum catalyst layer of membrane electrode assemblies (MEAs) after testing under different combinations of stressors. This was achieved by using conventional transmission electron microscopy (TEM) and particle size distribution analysis. The degradation mechanisms identified in this study include Ostwald ripening, platinum dissolution and redeposition, migration and coalescence, and carbon corrosion. Additionally, the possible respective drive cycles associated with these mechanisms are identified, providing crucial insights into the enhancement of fuel cell performance and durability.

#45 Self-Complementary Halogen-Bonded Tectons Enabling Multi-Dimensional Network Assembly in Molecular Crystals

Author(s): Gracie Holm, Junior, Chemistry
Mentor(s): Mike McGuirk, Michael Moghadasnia

Our research explores the extent to which self-complementary halogen bonding, as the primary mode of connectivity, can unlock new materials with desirable properties. Analysis of both molecular geometry and electronic structure through DFT-based calculations has identified the 2-iodooxazole moiety as a candidate to study halogen bonding for its self-complementary donor–acceptor geometry, desirable electronic properties and intuitive synthetic design. Previous investigations by our group have highlighted the propensity for the 2-iodooxazole moiety, installed on a linear, ditopic tecton to assembly into halogen bond-dominated, multi-dimensional, low-density network topologies through selective crystallization conditions. Our work aims to study how molecular geometry and changes in electronic structure influence the assembly of halogen bonding tectons with the ultimate goal being the assembly of low-density structures. This is done through the design and synthesis of planar and nonplanar multifold tectons, which act as intrinsic geometric restraints towards the assembly of dense networks. Additionally, both fluorinated and nonfluorinated tectons have been synthesized to further understand how modifying the intrinsic electronic properties of the molecule affect the overall network topology. By understanding the assembly of these halogen bonding systems at a fundamental level, new tectons can be utilized to produce highly crystalline materials with desired properties.

#46 One-Pot Synthesis of Mesoporous Cobalt Phosphate Used as a Catalase-like Nanozyme

Author(s): Davin Hughes, Sophomore, Chemical and Biological Engineering
Mentor(s): Brian Trewyn, Calvin Berstler

Being able to conduct multi-step chemoenzymatic catalysis in a one-pot system is a challenging task. A chemoenzymatic reaction represents a reaction where two or more consecutive transformations take place in a single reaction vessel. This process uses both enzymatic and chemical catalysis to more efficiently generate desired products from commercially available starting materials while removing the need to isolate intermediates. With new techniques to support employing enzymes and organic species within single-pot systems, the use of catalytically active mesoporous nanomaterials as enzyme supports has the potential benefits to enhance the performance of chemoenzymatic tandem systems. There are numerous advantages to using enzymes though they are costly and their functionality is limited to a small range of temperatures and pH levels. Because of this, enzyme mimics (Nanozymes) are very sought-after inorganic alternatives that are low-cost, high-stability alternatives. Here I explore a low-cost, high-efficiency method to synthesize a mesoporous cobalt phosphate (mCoPi) with the ability to transform hydrogen peroxide into water and oxygen and to be able to act as a catalase-like nanozyme in a variety of harsh local environments.

#47(O) Unraveling the Catalytic Mechanism of Nitrile Hydratase

Author(s): Kylie Knutson, Junior, Chemical and Biological Engineering
Mentor(s): Callie Miller, Richard Holz

I conduct research on the enzyme Nitrile Hydratase (NHase). NHase is a heterotetramer and is catalytically active when it is in its metalated state as Co3+ or Fe3+. Nitrile Hydratase can chemically convert a nitrile to its corresponding amide. This highly advantageous conversion makes NHase a promising biocatalyst for green industrial chemical processing, bioremediation, and pharmaceutical development. Investigating the active site of Nitrile Hydratase can aid in understanding its catalytic mechanism. It has been speculated that the active site Serine residue plays a key role in catalysis because it hydrogen-bonds with the water molecule that begins catalysis. To fully understand the significance of the active-site Serine residue it has been mutated to Aspartic Acid, Threonine, and Alanine in both iron and cobalt-type enzymes. Finally, catalytic activity, metal occupancy, and protein crystal structures of each mutant were analyzed. Electron Paramagnetic Resonance (EPR) was also used to shed light on structural changes to the iron-type mutants. In addition, a pH Study will be conducted to determine the relative activity of each mutant at various pHs ranging from 3-11.

#48(O) Characterization of peptide catalyst

Author(s): Alex Luong, Junior, Chemical and Biological Engineering
Mentor(s): Richard Holz, Callie Miller

Nitriles are turned into amides which can be used in polymers, feed stock, and drugs. This is done because amides are more reactive than nitirles. In industry, it is common to use acid and heat to turn nitriles into amides. This can be expensive especially when scaled up. This reaction can also be done with a class of metalloenzymes known as Nitrile hydratases. A peptide based on Pseudonocardiathermophilia's Nitrile hydratase (PtNHase) was made due to its active site being contain in one continuous amino acid string. The hope is that this peptide can become a biocatalyst for this reaction and be cheaper than current methods. Right now the peptide can not catalyze the reaction and this is where work is being done to figure out why. The peptide has been characterized via MALDI-tof, MCD, EPR, NMR, X-ray crystallography, and titration. Each of these methods have given a better understanding of how the peptide interacts with its metal center and how it folds.

#49 Chemically Tunable Biocompatible Hydrogels as a Novel Approach to Combatting Disease

Author(s): Katie Mann, Junior, Physics
Mentor(s): Dylan Domaille

Macrophages are immune cells that play diverse roles, from killing invading pathogens to coordinating the wound healing process. Unlike many cell types, macrophages are 'plastic', able to transition from their 'killing' role to their 'rebuilding' role in response to chemical cues. Remarkably, emerging evidence has shown that macrophage plasticity can also be activated in response to mechanical signals. In general, stiff environments promote a killing phenotype, while softer environments promote a wound-healing phenotype. We aim to design a biocompatible, chemically responsive implantable hydrogel which would provide a means to influence macrophage phenotype via mechanical cues. This material would present a novel approach to combatting complex diseases such as cancer. Polyethylene glycol (PEG) hydrogels are promising springboards for designing implantable materials due to their established biocompatibility and versatility. To implement controllable mechanical properties into the PEG hydrogel, we utilize dynamic covalent hydrazone/oxime bonds as the crosslinking bonds between the polymers of the material. We the resulting material will exhibit rapid dynamics (i.e., remain more fluid/soft) under physiological pH. Conversely, we hypothesize that the hydrogel will undergo oxidation upon exposure to inflammatory oxidative metabolites (e.g., those generated by tumor cells), causing the material to rapidly stiffen. Finally, we will analyze the efficacy of our hydrogel in triggering the transition of the macrophages from the 'healing' to the 'killing' phenotype by performing macrophage studies under varying mechanical conditions of the hydrogel. Successful design of this manipulable hydrogel would identify a novel way of reprogramming the immune system to combat disease using mechanical cues.

#50 Co-Crystallizations of Mixed Halogen/Hydrogen Bonding Tectons Towards Multi-Component Molecular Crystals

Author(s): Gemma Ponce, Sophomore, Metallurgical and Materials Engineering
Mentor(s): Michael McGuirk

Our research aims to understand hierarchical assembly of noncovalent interactions through co-tecton crystallization experiments. Previous work has provided a set of tectons optimized for strong, self-complimentary, halogen and hydrogen bonding interactions and demonstrated the ability to form single crystal domains with one-, two-, and three-dimensional halogen and hydrogen bonding connectivity. Using those same tectons we conduct co-crystallization experiments, verify the compositions of as grown crystals through Nuclear Magnetic Resonance Spectroscopy (NMR), and use single-crystal X-ray diffraction techniques to elucidate structural information of successful co-crystallizations. Specifically, we looked at both halogen bonding Tetons and their hydrogen bonding analogues with both fluorinated and non-fluorinated spacers. Fluorinated tectons have stronger σ-hole donors while non-fluorinated tectons have stronger σ-hole acceptors, lending to our hypothesis that this would facilitate stronger co-tecton halogen and hydrogen bonding networks, but the data we have currently collected indicates otherwise with no co-crystallizations between fluorinated and non-fluorinated tectons being successful. This suggests that while there are strong interactions between individual tectons, when templated over an entire single crystal domain there is an overall energetic penalty preventing co-crystals between fluorinated and non-fluorinated tectons.

#51 Utilizing Mesoporous Silica Nanoparticles (MSN) for transporting organometallic catalysts and exogenous enzymes for Intracellular synthesis of Biologically Active Molecules

Author(s): Rewa Raizada, Sophomore, Quantitative Biosciences and Engineering
Mentor(s): Brian Trewyn, Jaclyn Smith

The objective of this research is to design and fabricate multifunctional mesoporous materials with an iron core to hold and transport paramagnetic molecular catalysts and biocatalysts that are capable of synthesizing advanced molecules in intracellular environments. Mesoporous Silica Nanoparticles (MSN) have large surface area and can be used as drug carriers. Amine functionalization of MSN helps with dispersion, while paramagnetic component can assist in directed drug delivery under external magnetic field. Two distinct methods were employed for the manufacture of the nanocarriers. The first method involved a solvothermal synthesis of ferric oxide using Ferric chloride hexahydrate (FeCl3•6H2O), ethylene glycol (EG), sodium acetate anhydrous (NaAc), ethanol (EtOH), and polyacrylic acid (PAA). The ferric oxide was then treated with cetyltrimethylammonium bromide (CTAB), tetraethyl orthosilicate (TEOS), to form the magnetic iron oxide mesoporous silica nanoparticles (Fe3O4@mSiO2). This method resulted in an average surface area of 56.5415 m2/g; desorption-based pore volume of 0.1084545 cm3/g and mode pore diameter of 3.3 nanometers. The second process involved manufacture of amine-functionalized Fe3O4/Mesoporous Silica Nanoparticles (MSNs) using coprecipitation by treating FeCl2•4H2O and FeCl3•6H2O with sodium hydroxide, and then reacting the resultant iron oxide with CTAB and TEOS to form iron oxide mesoporous silca nanoparticle. Fe3O4/MSN-NH2 was then prepared by reaction of Fe3O4/MSN with (3-Aminopropyl) triethoxysilane in ethanol. This approach yielded an average surface area of 461.58 m2/g; desorption-based pore volume of 0.376 cm3/g and mode pore diameter of 3.43 nanometers. The findings demonstrate the second method is superior for more efficient targeted drug delivery.

CIVIL AND ENVIRONMENTAL ENGINEERING

#52 Microbial Plastic Degradation

Author(s): Sophia Lee, Senior, Chemical and Biological Engineering
Mentor(s): John Spear

Last summer, the Quantitative Biosciences and Engineering field session investigated a plastic-degrading enzyme, employing gene editing techniques to enhance its stability. This subsequent research takes a step back to look at microbial communities as a whole to address the problem of microplastics contamination in water systems. Microplastics in our environment poses significant health concerns, with exposure occurring through ingestion, inhalation, and dermal contact. These particles have been associated with a range of adverse effects, including oxidative stress, DNA damage, organ dysfunction, metabolic disorders, immune responses, neurotoxicity, as well as reproductive and developmental toxicity (1). Estimates conducted by the UN Environment Programme have found the annual global presence of microplastics in rivers to range from 31 kilo tons to 2.31 million tons (2). Given the size of microplastics, conventional filtration methods face considerable challenges in effectively removing these pollutants from water sources. In addressing this multifaceted issue, a comprehensive solution must incorporate both filtration and degradation mechanisms. The current research aims to address this challenge by exploring the potential of utilizing a biomat for simultaneous filtration and degradation of plastic contaminants.

#53(O) Global Material Flow Analysis for Macro and Micro Plastics with Emphasis on Plastics Lost to the Environment

Author(s): Madie Addis, Senior, Chemical and Biological Engineering
Mentor(s): Amy Landis

Plastic is one of the most widely consumed materials worldwide, and its impact on our ecosystems is undeniable. Plastic waste reduction initiatives have gained momentum in recent years, but the efforts of such initiatives don't always align with significant positive impacts. This study demonstrates a Material Flow Analysis (MFA) aimed at quantifying global flows of plastic, from production to end of life, ultimately identifying where plastic reduction efforts can be most impactful. On a global scale, plastic production and material flow data is lacking, so calculations in this analysis relied heavily on data published in the United Nations' 2015 Mapping Global Plastics Report. The global MFA includes macro and micro plastic flows and was conducted with a specific emphasis on end of life and flows lost to the environment. Results show that plastics lost to the environment only made up about 2% of the total mass of plastics, but that 2% equated to over eight million metric tons. These lost plastics stem from a variety of sources, making the issue difficult to tackle, but addressing this loss is important, nonetheless. Additionally, the MFA conducting specifically for plastics lost to the environment showed the mass of plastics ending up in the environment is much greater than the global MFA alone predicts. Reducing demand for plastic production through decreased plastic use is an obvious approach to minimize plastic waste and pollution, and this study provides insight about which plastics pose the greatest environmental threat, thus guiding where efforts should be focused.

#54 Microbes and Sulfur in a Cave and Karst System

Author(s): Sasha Robinson, Junior, Quantitative Biosciences and Engineering; Katy Essenburg, Sophomore, Quantitative Biosciences and Engineering
Mentor(s): John Spear

Shoshone Canyon Conduit Cave lies five miles west of Cody, Wyoming, and was found during the building of an irrigation tunnel through Cedar Mountain by the Bureau of Reclamation (BoR). As the cave lies within the tunnel, it can only be accessed with permission during the non-irrigation time of year. What makes this cave special is the high number of sulfides and sulfur deposits, alongside the many unique speleothems. To get a better understanding of the ecosystem and development of this karst system, a geobiological survey was completed of the microbiology and mineralogy of this sulfur cave on its speleothems, mineral deposits, and water. An analysis of the microbial population was done through small subunit ribosomal 16S rRNA gene analysis, prepared using a polymerase chain reaction

(PCR) to amplify Bacteria and Archea. Within the low biomass we found more Bacteria over Archea, with a prevalence of sulfur metabolizers. Three especially interesting taxa present were Acidithiobacillus, Anaerolinacaea, and Ferroplasma. Petrography done on the mineral and speleothem samples showed diverse crystal growth, while X-ray diffraction (XRD) and energy-dispersive X-ray spectroscopy (EDS) showed a variety of mineral morphotypes. With the amount of elemental sulfur in the cave, the taxa present, and the speleothems present, it is likely that this cave contains a semi-isolated complete sulfur cycle. Findings from this research can help to develop a greater understanding of the geobiology of sulfur karst systems, not just in the Rocky Mountains and the Greater Yellowstone Ecosystem.

#55 Regionalized Material Flow of Plastics within the Caribbean

Author(s): Lydia Allison, Sophomore, Civil and Environmental Engineering; Anna Williams, First-Year, Geophysics
Mentor(s): Amy Landis

Understanding plastics' impact on the environment is essential due to their widespread use as a basic commodity. Growing plastic utilization has put additional pressure on waste management organizations to keep up with growing plastic flows. Despite the growth of plastic research, most studies have focused on quantifying macro and micro plastic material flows within major economic powers that have prior waste management systems in place; specifically the European Union and the United States. Our research aims to quantify both the macro, micro, and nano plastic flows within the Caribbean, with an emphasis on the Dominican Republic, to help guide waste collection efforts. Preliminary data collection focused on comprehending the region's current waste generation and management and developing a Caribbean material flow using literacy review methods. Tourism, weather patterns, and waste infrastructure all play a role in the quantification of plastic flows with the Caribbean. Assessing each country's ability to implement waste management strategies given their needs, will result from continuing to gather data on the availability of sanitary landfills vs open air landfills.

#56 Hydrothermal alkaline treatment for destruction of lithium-ion battery-derived PFAS

Author(s): Sean Brooks, Sophomore, Chemical and Biological Engineering
Mentor(s): Timothy Strathmann, Shilai Hao

Lithium-ion batteries (LiBs) are widely used in electric vehicles, consumer electronic devices, and renewable energy storage systems. Previous reports showed bis-perfluoroalkyl sulfonimides (bis-FASIs), an emerging class of PFAS that are commonly used as electrolytes and cathode binders in LiBs, have the potential to be released into the environment and enter drinking water supplies. However, little research has examined the treatment/destruction of bis-FASIs to date. Hydrothermal alkaline treatment (HALT), which utilizes subcritical water (e.g., 180-370 °C and 1-16 Mpa) amended with strong alkali, has been demonstrated to destroy a variety of legacy PFAS in a wide range of matrices. Herein, we evaluated the effectiveness of HALT for destruction of bis-FASIs. Results showed bis-FASIs can be fully mineralized to fluoride under certain HALT conditions. The fate of nitrogen, sulfur, and fluorine in bis-FASIs during HALT was investigated, and a mechanism is proposed. This presentation will also discuss important environmental implications of bis-FASI treatment.

#57 Optimization of Hydrothermal Destruction of Per- and Polyfluoralkyl Substances

Author(s): Ann Daniels, Sophomore, Chemical and Biological Engineering
Mentor(s): Timothy Strathmann, Shilai Hao

The equipment required for the current methods to quantify of per- and polyfluoroalkyl substances (PFAS) in contaminated samples are costly and inaccessible to many PFAS research laboratories. The destruction of PFAS with hydrothermal alkaline treatment (HALT) produces inorganic fluorine ions (F-) which can be easily measured with a fluoride ion selective electrode (F-ISE). Utilizing this, inorganic fluorine can be measured in post-treatment samples to determine total organic fluorine (TOF) present in the pre-treatment sample. HALT-TOF utilizes readily available equipment and can be used to rapidly screen for the presence of PFAS in both aqueous and soil samples. By optimizing HALT reaction conditions in samples with known concentrations of a wide range of PFAS, the mildest conditions possible required for complete defluorination will be selected to create a standard operating procedure for the destruction of PFAS in aqueous and soil matrices. HALT requires highly concentrated samples for most efficacious treatment. Solid and liquid phase extraction of collected samples through columns of granular activated carbon can be used to increase PFAS concentration of the original samples prior to HALT treatment. The results of this procedure will be confirmed through analysis with CIC, 19F-NMR, and HRMS in post-treatment samples.

#58 Reinventing Wastewater Treatment Plants: Energy Neutral Treatment and Enhanced Fertilizer Production Through a Novel Resource Recovery Center

Author(s): Jonathan Larmore, Sophomore, Quantitative Biosciences and Engineering
Mentor(s): Tzahi Cath

In this project the focus was on increasing the efficiency and viability of the removal of ammonia from wastewater through a chemical treatment, by way of manipulating the pH of the wastewater using sulfuric acid and a base solution. This removes the ammonia from the solution as a gas, by increasing the pH of the solution, and then into a salt when it comes into contact with the low pH distillate. That ammonia salt can later be recovered from the distillate as a valuable fertilizer and the feed solution more easily treated. Two of the advancements of this project is the change from a simulated feedstock to true wastewater conditions at an experimental treatment plant and the large scale of the current treatment.

#59 Hydrothermal Alkaline Treatment (HALT) of PFAS-accumulated Ferns: PFAS Destruction and Biofuel Production

Author(s): Emma Leszczak, Senior, Civil and Environmental Engineering
Mentor(s): Shilai Hao, Christopher Higgins

The overall goal of this project is to apply hydrothermal alkaline treatment (HALT) to PFAS-accumulated plants to destroy PFAS and produce biofuel simultaneously. Our previous study showed that HATL is a rapid, effective, and robust method for PFAS destruction in different PFAS wastes including aqueous film-forming foam (AFFF), AFFF-impacted groundwater and soil, spent GAC. The hydrothermal reaction has also been demonstrated to be an effective method for producing value-added biofuel (bio-oil and hydrochar) from lignocellulosic biomass over the past decades. While a recent study from Zhi et al. showed that ferns can accumulate PFAS from water, immobilize them in roots, and store them in harvestable tissue, the proper disposal of the harvested Ferns accumulating PFASs is a critical need since the common solid waste disposal options including landfill and compost have a risk of releasing PFAS to the environment again. As such, we propose a series of tasks to evaluate the effectiveness of HALT to destroy PFASs in the harvested plant and to produce biofuel. Results from this project may provide the current PFAS remediation field with a novel PFAS remedial strategy by coupling phytoremediation and thermal-chemical treatment.

COMPUTER SCIENCE

#60 Preventing Cheating in Online Multiplayer Gaming

Author(s): Tylor Bray, Senior, Computer Science
Mentor(s): Guannan Liu

Nowadays, online multiplayer gaming has grown into a multi-billion-dollar industry, connecting billions of players through virtual worlds. To ensure players have real-time, low-latency interactions, a client-server architecture is employed to offload computations to the players' personal machines. However, these machines are considered untrusted. Players intentionally cheat by making use of external tools to gain unfair advantages. This cheating not only diminishes the gaming experience for 'honest' players but also disrupts the equity of online competition and significantly impacts publishers' revenue. To counteract this issue, Anti-Cheat (AC) systems are developed to uphold the integrity of online games. Our research aims to investigate the unique cybersecurity challenges that AC systems encounter and to propose robust methods to further secure online multiplayer games.

#61 Memory Contention Sidechannel Communication Vulnerability

Author(s): James Crea, Senior, Computer Science
Mentor(s): Mehmet Belviranli

We present work on a novel side channel vulnerability that facilitates covert communication between colluding malicious applications, such as on a smartphone. By intentionally creating memory access patterns that lead to memory contention, these applications can detect the contention and use it as an unintended communication channel. This method allows for the aggregation of user-granted permissions across multiple apps, undermining the security principle of least privilege, which is designed to limit permissions to the minimum necessary for app functionality. Additionally, this vulnerability could enable unprivileged websites to deduce the presence of other applications running on the same device. The implications of this attack are far-reaching, necessitating further research into mitigation strategies to protect against such exploitation.

#62 Evaluating Website Security: A Study on Content Security Policy Implementation

Author(s): Isa Fernandes de Oliveira, Junior, Computer Science
Mentor(s): Chuan Yue, Mengxia Ren

Content Security Policies (CSPs) are vital defenses against cross-site scripting (XSS) and unauthorized web resource manipulation. This study investigates CSP implementation across the top 100 websites listed in TRANCO, focusing on resilience to external manipulation. Our analysis reveals that over 50% of domains lack adequate protection against XSS attacks, despite CSP implementation. Vulnerabilities include the misuse of 'unsafe-inline' directives and reliance on white-listing-based policies over nonce-based alternatives. These findings highlight the need for a comprehensive CSP approach, prioritizing script and web control. Strategies to enhance website security, such as stricter CSP configurations, are discussed, emphasizing nonce-based strategies and comprehensive directive coverage.

#63 Evolution of The DECtech Program

Author(s): Bodie Lutz, Senior, Computer Science
Mentor(s): Christine Liebe

The DECtech program, serving students ages 8 - 15, at Colorado School of Mines is an outreach program focused on early access STEM education. DECtech began with after-school classes exclusively for girls and summer camps for all genders, recently expanding DECtech to after-school classes for all genders. As the program evolves, it is imperative to understand how its influence has shifted and how to remain financially stable for the future. Through quantitative analysis of enrollment statistics and financial data, the program's influence, growth, financial well-being, and fiscal viability were revealed, and a financial sustainability plan was devised to promote its self-sustainability. Results have shown that over DECtech’s life, enrollment numbers have decreased, likely due to the global pandemic and its economic effects. However, as the program has continued to open access to more students, there has been a sharp increase in enrollment as of spring 2024. As enrollment into the program has altered, the sources of funding have changed, and to remove the reliance on external funding, it is necessary to increase prices to ensure self-sufficiency of the program. With the changing horizons of DECtech, it is necessary to continue to provide increasing opportunities for early STEM education for children all around Colorado, not only to increase education in disciplines of STEM, but to ensure the financial sustainability and security of the program. With the new understanding of DECtech’s enrollment and its financial position, the path to increase STEM education across Colorado is clear.

#64 Holistic Path Planning for Multi-Drone Data Collection

Author(s): Ava Moon, Sophomore, Computer Science; Cody Fellinge, Junior, Computer Science
Mentor(s): Qi Han

We address the challenge of planning and deploying a team of Unmanned Aerial Vehicles (UAVs) for data collection from wireless sensors while minimizing collection latency. Previously, our method lacked accuracy due to a lack of adaptability to drones encountering connectivity issues during missions. To remedy this, we propose a solution that integrates both offline and online planning strategies. Our solution involves first forming an offline plan before deployment, considering connection and energy constraints, and then switching to an online strategy to handle sensor failures and the random nature of wireless communication. Central to our approach is the development of an algorithm that allocates energy resources efficiently between offline path planning and online adaptation. We conducted field tests to validate our methodology, collecting empirical data on energy consumption and connectivity patterns using both simulation and a physical UAV and wireless sensor testbed. Using this data, we fine-tuned our algorithm to determine the optimal energy allocation strategy for maximizing mission success rates. This research significantly enhances the reliability and adaptability of multi-drone data collection.

#65 This and That: Modeling Cognitive Status in a Multimodal Environment

Author(s): Polina Rygina, Junior, Electrical Engineering
Mentor(s): Tom Williams, Mark Higger

Cognitively Informed Language Generation is a computational task involving the creation of human like language based on the cognitive status of entities in discourse. In the context of this work, cognitive status refers to the amount of attention, or salience, an entity has in discourse. For robotics, cognitively informed language generation could facilitate more effective communication between humans and other agents, necessitating an understanding of how humans generate language. This work aims to develop accurate coding guidelines to model the cognitive statuses of various objects when analyzing video footage using multimodal properties. By leveraging the Givenness Hierarchy, a linguistic theory that describes how humans use different pronouns and noun phrases to describe objects in discourse based on their salience, the purpose of coding cognitive statuses is to manipulate the environment for open world reference. The coding scheme involves the Givenness Hierarchy and incorporates gestures to capture cognitive statuses. Gestures help provide additional context that would normally be lost in language, thus adding them into the guidelines informs cognitive status more accurately. Videos from a study on gesture generation in individuals were analyzed using this coding scheme to develop a corpus for future use in referring expression generation, referring form selection, and ordering of task instructions. Future work will evaluate the effectiveness and reliability of this coding scheme across various contexts and datasets.

#66(O) Evaluating the Effects of Performative Autonomy for Robots with Communication Latency

Author(s): Cailyn Smith, Junior, Computer Science
Mentor(s): Tom Williams

In space exploration contexts with collaborative human-robot teaming, it is important for human teammates to maintain Situation Awareness (SA) about their ongoing tasks and for robot teammates to be trustworthy. However, space exploration contexts are marked by significant communication latency, which can impact human-robot teaming. Performative Autonomy is a strategy in which a robot intentionally interacts at a lower level of autonomy in order to boost human teammates' SA. While prior work has shown that robots using PA strategies in latency-sensitive space contexts are perceived by humans as better teammates, the impact of PA strategy on the trust placed on robots has not been assessed. Therefore, in this work we present the results of an experiment designed to evaluate the impact of latency and PA strategy choice on trust, SA, perceived intelligence, and additional factors. Our results suggest that lower performative autonomy leads to increased cognitive load when latency is present. In addition, we observed no effect of PA strategies on human SA levels, contradicting the findings from previous work on PA. Finally, robots operating under higher latency were perceived to be less trustworthy and intelligent.

#67 Homeguard: Safeguarding User-Centric Privacy in Smart Homes Using AI@EDGE

Author(s): Dhruva Sogal, Senior, Computer Science
Mentor(s): Dong Chen

Internet of Things (IoT) Devices leveraging Machine Learning (ML)-based techniques used in many homes come with a range of privacy risks. We propose executing ML frameworks locally on IoT devices to eliminate the need to send user data to data centers. To better understand the capabilities and limitations of ‘local ML’ systems, the goal of this project was to create a benchmarking tool to predict the performance of ML frameworks on IoT devices. Performance data of a full-scale computer vision framework, a mobile device-oriented object detection framework, and support vector machine at various CPU frequencies, memory thresholds, and total activated core counts on a Raspberry Pi 4 were collected. Analysis of this data indicates 2 key findings 1) Consistent with previously obtained results, there are machine learning models that can perform with very low (500 mb) memory, and increasing the memory allocation for these models has no significant impact on performance and 2) While full-scale computer vision algorithms (Yolo v5) perform poorly (0.5 fps) at low memory/CPU frequency specifications, ‘lite’ object detection frameworks and support vector machine methods can be successfully run. Using this data, a regression model was constructed for performance prediction.

ELECTRICAL ENGINEERING

#68(O) Quantum Cascade Laser-Based Vibrational Circular Dichroism

Author(s): Roya Akrami, First Year, Electrical Engineering

Mentor(s): Yamuna Phal

Afflictions such as Alzheimer's Disease can be discovered early on in a patient through the microscopic detection of its biomarkers. Quantum Cascade Laser-Based Vibrational Circular Dichroism (QCL-VCD) is becoming a more sought-after method to quickly and accurately map a patient's cells for these biomarkers. This study aims to explore the best QCL-VCD techniques, by exploring the method's origins and relevant optical setups. By understanding the systems leading up to QCL-VCD—from Optical Rotatory Dispersion to Constant Source Circular Dichroism—we aim to optimize the data processing of the QCL-VCD. Ideally, we will be able to reduce noise and amplify the chiral signals we require during data collection. Through our work, we aspire to enhance the QCL-VCD microscope's precision and speed in biomarker detection.

#69 Advanced LSTM Forecasting for EV Charging Station Demand: A Case Study from Pasadena, CA

Author(s): Owen Cornmesser, Senior, Electrical Engineering
Mentor(s): Qiuhua Huang, Asmaa Romia

In recent years, the surge in electric vehicle (EV) sales has necessitated the expansion of EV charging infrastructure, presenting new challenges in managing the variable charging patterns essential for maintaining power grid stability. This study leverages EV charging data from a fast-charging station in Pasadena, CA, combined with weather data from the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM), to implement a Long Short Term Memory (LSTM) model tailored for forecasting 15-minute interval load demands at the charging station. The LSTM model, chosen for its proficiency in handling complex time-series data with long-term dependencies, demonstrated robust forecasting accuracy results in Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and in the R^2 score. These findings underscore the potential of integrating advanced forecasting models into EV infrastructure and grid management systems, suggesting a pathway toward a more resilient and adaptive power grid in the face of increasing stochastic demands.

#70 Wireless Nano-VNA S-Parameter Monitoring for Biomedical Applications

Author(s): Lisa Elmiladi, Senior, Electrical Engineering
Mentor(s): Peter Aaen

The dynamic monitoring of biological metabolites, such as glucose and lactate, plays a pivotal role in healthcare diagnostics and sports science. Current research focuses on remote sensing techniques utilizing on-body resonant antenna or circuitry to track metabolite concentrations through frequency variation. Traditional vector network analyzers (VNAs) used for this purpose are generally bulky and tethered, limiting their applicability for ambulatory subjects. This presentation introduces an innovative enhancement of a compact handheld VNA, the NanoVNA-H, custom-modified with integrated Wi-Fi and Bluetooth capabilities. This advancement eliminates the encumbrance of cables, enabling the VNA to be compactly mounted on a patient and permitting unimpeded movement. The system is designed to wirelessly relay measurement data to a remote base station for real-time analysis, significantly improving the practicality of continuous, on-body metabolic monitoring.

#71 Remote S-Parameter Communication from NanoVNA

Author(s): Kenny Hora, Junior, Electrical Engineering
Mentor(s): Atef Elsherbeni, Peter Aaen

Measurement of biological metabolites, such as glucose and lactate are important in both healthcare and athletic settings. Research is currently being conducted on remote sensing approaches to these metabolites, many of which use on-body antenna or resonator circuits that measure changes in resonant frequencies to determine the concentrations of the metabolite. However, these approaches use conventional laboratory VNAs, which are impractical for on-body measurement of moving subjects due to their size. A software program was developed for a small handheld vector network analyzer (NanoVNA) that allows it to be attached to a single-board computer and attached to the subject being measured. This permits the subject to move freely while measurements are wirelessly transmitted to a base station where they can be further analyzed.

#72 Multiphysics Optimization of GaN-Based Power Transistors for 5G mm-Wave OperationIC Design and Optimization for 28 GHz GaN Radar Power Amplifier

Author(s): Jack Marley, Junior, Electrical Engineering
Mentor(s): Peter Aaen

This project's objective is to optimize Gallium Nitride (GaN)-based power transistors for use in mm-wave advanced radar applications. As operational frequencies approach 30 GHz the efficiency of transistors becomes a concern. Using a multiphysics simulation methodology, with the integration of electromagnetics and nonlinear transistor models, we've simulated the electromagnetic propagation within the transistor and its impact on output power and efficiency. This analysis examined various feeding structures within the transistor and it shows promise to optimize the performance. Using the simulated high-frequency voltages and currents within the transistor provides insight for designers to optimize the layout and design of a power transistor. Additionally, these simulations can be used to help explain measured temperature distributions.

#73(O) Implications of Engineering and Education Professor's Problem-Solving Mindsets on Their Teaching and Research

Author(s): Ryan Miller, Junior, Electrical Engineering; Alexis Capitano, Senior, Electrical Engineering
Mentor(s): Katie Johnson

Engineering has a reputation as a "problem solving" field, and many aspects of engineering education aim to prepare its future professionals to solve problems they may face in the real world. However, often the problem defining (or problem identifying) phase of the problem-solving process is less visible, which has the potential to bias solutions. This paper seeks to understand the qualities of a problem-solving mindset that are illustrated in faculty interview data and how these mindsets impact the interviewees' academic responsibilities, especially with respect to teaching and research. The interviews we analyzed included two faculty in the School of Engineering and two in the School of Education at a public university in Western Canada. By conducting the analysis, we hope to better understand a problem-solving mindset and its implications for engineering education.

#74 Flexibility-Based control of Communities of Grid Interactive Buildings

Author(s): Maverick Savage, Sophomore, Electrical Engineering
Mentor(s): Qiuhua Huang

This project's goal is the control of community-scale clusters of grid interactive buildings to reduce homeowner electricity burden and increase resiliency while providing services to the grid. Energy management systems for individual buildings are fairly well established, both in literature and implementation, but a system that controls many of these buildings based on near-real-time quantification and aggregation of the buildings' heterogeneous flexibility remains an open research problem with great application potential. To address the gap, the project proposes a community-scale coordinator that will aggregate the load and flexibility of individual buildings using measurements from smart meters and sensors to ensure the operational constraints of the grid aren't violated and to enable residential demand response with higher degree of flexibility and certainty. A data-driven model based on these measurements will be developed to forecast the flexibility in both the short-term and day-ahead time windows. For community-level control and coordination, both the forecasted flexibility and fairness are important considerations. Social fairness will be included in the new coordination/scheduling method to allow the coordinator to distribute the desired load and changes in operation fairly while respecting occupant preferences.

#75 An Interactive Visualization of Electrostatic Electric Field and Potential Distribution

Author(s): Charles Vath, Senior, Electrical Engineering
Mentor(s): Atef Elsherbeni

A MATLAB app to visualize the resultant electric potentials and or fields emanating from point charge(s) that the user can interactively create and edit. The number of charges, the location of the charge(s), and the magnitude and polarity of the charges can all be user defined. Additional options include: placing charges via use of a button and hovering over and clicking inside the computational domain, moving existing charges by clicking and dragging, and adjusting a point charge's magnitude with a slider. Such user interactions can also update the domain axes not only after the input parameters process is completed, but also in near real-time computations. One can choose between viewing the resultant electric fields, approximate voltage contours, or both, and create figures bearing such information about the electric field and approximate voltage contours.

ENGINEERING, DESIGN, AND SOCIETY

#76 Investigating Student Experiences of Inclusion and Exclusion to Guide Makerspace Development

Author(s): Bee Alcorn, Senior, Geology and Geological Engineering; Julianne Stevens, Sophomore, Engineering, Design, and Society
Mentor(s): Aubrey Wigner

A sense of belonging is vital to the success of engineering students during their academic journey. At our university, first year students' design experiences will be tied in deeply with our new flagship makerspace and fabrication facility. By creating a welcoming and inclusive space that ties into students' first year we hope to increase retention and recruitment rates, particularly for traditionally underserved students. Conversely, the feeling of being excluded can lead students to leave STEM majors or drop out of university entirely. Mistakes in terms of makerspace culture can be costly in terms of diversity by pushing out students who otherwise are borderline in their perceptions of belonging in STEM programs and institutions. To better understand how to create a welcoming makerspace, and avoid exclusionary practices, our research team collected and analyzed student experiences of inclusion and exclusion at our university. Our research team conducted 26 qualitative interviews to understand the institution-specific experiences of inclusion and exclusion felt by students. Each interview lasted between 30 and 75 minutes. The results were analyzed using applied thematic analysis. This study had a focus on the experiences of non-traditional, LGBTQ+, underserved minority, and women students as well as students with disabilities but was also open to majority categories as well.

#77 Investigating Student Experiences of Inclusion and Exclusion to Guide Makerspace Development

Author(s): Cate Corry, First Year, Quantitative Biosciences and Engineering
Mentor(s): Aubrey Wigner

A sense of belonging is vital to the success of engineering students during their academic journey. At our university, first year students' design experiences will be tied in deeply with our new flagship makerspace and fabrication facility. By creating a welcoming and inclusive space that ties deeply into students' first year we hope to increase retention and recruitment rates, particularly for traditionally underserved students. While a sense of belonging can lead to higher retention and persistence, the feeling of being excluded can lead students to leave STEM majors or drop out of university entirely. Mistakes in terms of makerspace culture can be costly in terms of diversity by pushing out students who otherwise are borderline in their perceptions of belonging in STEM programs and institutions. To better understand how to create a welcoming makerspace, and avoid exclusionary practices, our research team collected and analyzed student experiences of inclusion and exclusion at our university. This study had a particular focus on the experiences of non-traditional, LGBTQ+, underserved minority, and women students as well as students with disabilities but was not

exclusive to those categories. Our research team conducted 26 qualitative interviews to gain an understanding of the institution specific experiences of inclusion and exclusion felt by students. Faculty and administrators were also interviewed to better understand the goals and DI&A initiatives pertaining to campus culture. During this project, the research team engaged with their students as stakeholders in the identification of best practices leading to a diverse and inclusive culture in our new makerspace. By discovering what individual students and stakeholder groups value and expect of an inclusive maker/innovation space the research team was able to provide guidance to campus leaders and the makerspace director to help create a makerspace culture where students can learn, grow, socialize, and enhance their engineering identity. This paper shares both the method for how a deep, site specific, study of inclusion and exclusion was performed as well as a literature grounded set of recommendations for how to create an inclusive makerspace culture. While the recommendations are site specific to our university, we expect some of the practices to be universally helpful and for the methodology to be useful to anyone interested in better understanding their university's culture.

#78(O) Explorations of Engineering Identity Formation and Gender Expression

Author(s): Lucy Gilbert-Fagen, Junior, Engineering, Design, and Society
Mentor(s): Dean Nieusma, Kylee Shiekh

This research project seeks to investigate the intricate relationship between gender identity and engineering self-conceptualization among undergraduate engineering students. The primary objective is to gain a nuanced understanding of how engineering students perceive and actualize their gender identity within the context of their chosen field. Through in-depth interviews, this study will explore the intersectionality of gender and engineering identities, aiming to unravel the unique aspects and connections that define the experience of being an engineer through the lens of gender. The research methodology involves conducting semi-structured interviews, allowing for comprehensive exploration of each student's lived experiences. These interviews will assist to identify patterns, themes, and connections that shed light on the complex interplay between gender identity and the conceptualization of an engineering identity. By delving into these inquiries, the research intends to contribute valuable insights into the broader conversation on diversity and inclusion within STEM fields. This project holds significant implications for academia, policy, and industry by providing a foundation for understanding the multifaceted experiences of engineering students, particularly those related to gender identity. As we strive for more inclusive and equitable environments within STEM disciplines, this research seeks to inform strategies that foster a supportive and diverse community for future engineers.

#79 Optimization of Shallow Geothermal Energy

Author(s): Camille Neuder, Junior, Physics
Mentor(s): Mark Flordia

This project focuses on using shallow geothermal energy to provide clean and optimal energy to a 2000 square foot house test site in Dodge City, Kansas. The described test site aims to maintain a consistent temperature of 70°F year-round, 24 hours per day, using the most efficient methods of geothermal energy for the local environment. The identified solution involves a vertical loop with an open-source pumping system from the local aquifer connected to a heat pump. The results demonstrate that cooling can be effectively managed with circulating water from a shallow aquifer, while heating to 70°F requires supplemental energy due to the aquifer's temperature of 60°F. The mechanical and heat transfer process design can be adapted to provide efficient heating and cooling to multiple houses, facilitating an expansion from individual residential use to neighborhood access by connecting houses with horizontal loops. The analysis techniques used in this study can be extrapolated to any location, considering that each location will have different temperature profiles and aquifer depths to extract heat and cooling mediums.

GEOLOGY AND GEOLOGICAL ENGINEERING

#80 Fallout Radionuclide-based investigation of post-fire dry ravel mechanics in cohesive soil aggregates

Author(s): Samantha Burton, Junior, Geophysics
Mentor(s): Danica Roth

Nonlocal sediment transport processes involving long-distance particle motion can contribute significantly to fluxes in steep landscapes. However, these processes are not adequately represented by commonly used flux models, which disregard the influence of upslope topography on long-distance particle motion. Probabilistic, particle-based sediment transport models have recently been developed to address this, but have not yet been tested in a natural environment. Here, we investigate the transport process of dry ravel, the rolling, sliding and bouncing of sediment for long distances across the ground surface, which can contribute to elevated erosion rates and hazards after wildfire. We analyze short-lived fallout radionuclide concentrations (210Pb) in individual granular soil aggregates (~1-3 cm diameter) deposited by dry ravel along a hillslope burned by the 2020 SCU Lightning Complex Fire in the Mt. Diablo Range of central California. We find that meteoric excess 210Pb content decreases with radial depth into individual aggregates, suggesting that soil aggregates generally stay intact as they travel downslope over annual to decadal timescales. The presence of radionuclide concentration gradients within soil aggregate granules introduces new considerations when interpreting radionuclide concentrations in soil samples incorporating multiple aggregates, e.g. in soil cores. This is particularly relevant when transport processes are particle size-dependent or lead to size-dependent sorting and deposition, as we observe for dry ravel at this site. A better understanding of long-distance sediment transport process mechanics will both improve sediment fingerprinting methods in soils with stable aggregates and enable more accurate predictions of the impacts of changing environmental factors on landscapes.

#81 Presence of Millennial-Scale Climatic Cycles During the Middle Eocene Climatic Optimum

Author(s): Maddie Fox, Junior, Civil and Environmental Engineering
Mentor(s): Piret Plink-Bjorklund

The Eocene epoch (55-34 million years ago) witnessed a transition from a greenhouse to an icehouse climate, marked by rapid, extreme global warming events known as hyperthermals. These events, triggered by spikes in atmospheric CO2 concentration, offer insights into Earth's response to high-magnitude CO2 changes, crucial for comprehending modern climate shifts. One such event, the Middle Eocene Climatic Optimum, was a major climatic shift lasting approximately 500 kyr. Orbital forcers, most notably variations in the amount of solar irradiance reaching Earth, are believed to explain many of the observed climatic variations in both this epoch and others. Changes in orbital patterns are widely believed to explain cyclicities on the 20,000 to 100,000 year scale, while changes in solar irradiance have effects on the sub-1,000 year scale. However, little work has been done to understand the influence of orbital cycles of periods between these, in the millennial range. This study investigates Middle Eocene Climatic Optimum temperature proxies from Ocean Drilling Program sites, revealing a statistically significant 2500 ± 250-year cycle, identified as the Hallstatt cycle. Linked to a spin-orbit coupling of Jovian planets, this astronomical origin suggests that solar system chaos during this period played a role in abnormal climate patterns. Understanding such complexities enhances predictions about current and future climates by acknowledging the substantial influence of external factors on climate dynamics.

#82 Mima Mounds of the Puget Lowland: Rediscovering Their Place in Washington's Proglacial History

Author(s): Isaac Pope, Junior, Geology and Geological Engineering
Mentor(s): Danica Roth

Mounded ("Mima mound") topography has posed a baffling geomorphological mystery for over a century. Found across North America, these features have spawned hypotheses ranging from biotic to seismic attempting to explain the origins of mound fields. We investigated the type locality of Mima Mounds in the Puget Lowland to reconstruct their place in Western Washington's proglacial history. Using high resolution DEMs, we mapped over 160 sq. km of mounded topography. We find that these mound fields primarily mantle Vashon Stade proglacial terraces and outwash channels, often extending across multiple terrace levels and braided gravel outwash channels below. A strong preference is shown to gravelly over sandy substrate. At Mima Prairie, the mounds drape across the periphery of the proglacial terrace onto the kettled topography below where they may be found in the bases of kettles. Occasionally found among the mounds are exotic plutonic boulders that do not correlate with the underlying gravels, these boulders instead being reminiscent of glacially rafted boulders common in kettles. Similarly, the mounds can be found both on elongated cobble platforms or "gravel pedestals" and over lenses where the mound material forms an "anti-mound" depression into the substrate. Altogether, this suggests that mounded terrain was built on an uneven and occasionally kettled topography. The nearly exclusive concurrence of mounded topography and proglacial features demonstrates the importance of considering these mounds

as components of an interconnected system subject to the processes and history of their proglacial environment.

#83 Bioturbated Dry Ravel and Soil Mixing in a Post-Wildfire Environment

Author(s): Eliza Ross, Sophomore, Geophysics
Mentor(s): Danica Roth

The average wildfire risk in the Western United States is on the rise due to climate change. Wildfires act as potent agents of weathering, triggering the mobilization of dry ravel sediment and often resulting in a temporary surge in sediment transport rates and associated debris-flow hazards. Existing hillslope sediment flux models fail to adequately capture the complex dynamics of erosion and deposition, particularly after wildfires and in landscapes dominated by complex processes like bioturbation (e.g. burrowing animals, tree falls, or other disturbances). To begin to understand bioturbated dry ravel and subsurface soil properties, we studied two hillslopes affected by the 2020 Santa Clara Unit Lightning Complex Fire at the University of California Blue Oak Ranch Reserve near San Jose, CA. Here, we employ a novel application of short-lived radionuclides to examine increased dry ravel transport rates due to fire disturbance. Gamma spectroscopy was employed to determine the concentrations of short-lived fallout radionuclide 210Pb/214Pb in soil cores and recently excavated material from squirrel burrows across a hillslope transect spanning from the channel to the ridge. Our initial findings indicate that the 210Pb/214Pb ratio in soil core sediment is spatially variable, but cores collected the same distance from the ridge maintain relatively consistent mean values down to a depth of 6 cm. Our observations suggest heterogeneous mixing within the soil layer at least to this depth, warranting further in-depth analysis of sediment characteristics at various depths to further investigate post-fire sediment transport in steeplands.

GEOPHYSICS

#84 Maximizing the value of Hyperspectral Data Using Automated Mineralogy

Author(s): Pablo Chang Huang Arias, Senior, Geophysics
Mentor(s): Eileen Martin, Katharina Pfaff

With an increasing demand for domestic raw materials and critical minerals, , there is an increasing need for rapid and precise methods of mineral characterization. This study focuses on leveraging machine learning algorithms to enhance the mineral characterization process of drill core using hyperspectral imaging and co-registered automated mineralogy data. The initial phase of the project included the development of an image masking algorithm using machine learning techniques. This algorithm efficiently distinguishes drill core (desirable information from drill core) and background (cardboard boxes, wood pieces, and smaller rock chips). The result is a structured methodology that can be applied to hyperspectral images and allows to train a Convolutional Neural Network (CNN) to automatically mask the hyperspectral data. In the subsequent phase, the research aims to develop a machine learning classification algorithm capable of identifying key minerals such as quartz and feldspar from hyperspectral scans. In traditional hyperspectral data interpretation, minerals such as quartz and feldspar are considered invisible as they lack so-called diagnostic features in the hyperspectral SWIR spectrum. The goal is to utilize machine learning to extract relevant features from hyperspectral curves and establish correlations with precise SEM mineral compositions, thereby making mineral characterization more efficient. To accomplish this goal, training labels are derived from Scanning Electron Microscope (SEM) - based automated mineralogy data to ensure accuracy. Overall, this study significantly advances mineral characterization techniques in the mining sector by seamlessly integrating machine learning methods with hyperspectral data analysis. The key highlight is the provision of labeled and commented code progress, offering a valuable resource for future development endeavors. The open-source nature of the developed code, available and released through Github at @pablochanghuang, facilitates collaboration and ongoing innovation in the field of mineral characterization. This approach not only enhances accuracy and efficiency but also fosters ongoing innovation in this field.

#85 Imaging with Correlated Random Sources

Author(s): Cash Cherry, Junior, Applied Mathematics and Statistics
Mentor(s): Eileen Martin

Seismic imaging is a collection of techniques that use vibrations traveling through the ground to infer maps of the materials those vibrations traveled through (e.g. soils, rocks). Over the past twenty years, a seismic imaging technique known as ambient seismic noise interferometry has enabled seismologists to use long recordings of vibrations generated by random vibration sources as a source of energy to image the Earth. For successful imaging, these random sources must follow certain uniformity and independence assumptions. However, in populated areas and around machinery, we often encounter non-ideal source distributions, including spatially or temporally correlated vibration sources. Vehicles traveling over bumps are a common example of correlated sources. Using data from a roadside array in Fairbanks, Alaska, we take a different approach and analyze the information available from vehicle sources.

#86 Unlocking the Subglacial Realm: Leveraging Machine Learning for Efficient Identification of Subglacial Lakes

Author(s): Ana Horne, Senior, Applied Mathematics and Statistics
Mentor(s): Matthew Siegfried, Wilson Sauthoff

Subglacial hydrology connects glacial and oceanic systems, modulates ice dynamics, and remains a major physical uncertainty in future ice-sheet projections. Subglacial water is often stored in subglacial lakes, some of which are active, episodically filling and draining on short timescales. Lake drain-fill cycles cause changes in water distribution, grounding-zone stability, and freshwater flux and nutrient and carbon export into the Southern Ocean and sub-ice-shelf cavities. However, traditional methods for identifying subglacial lakes involve geophysical surveys which can be time-consuming, expensive, and in some cases impossible. This study presents an alternative approach to efficiently and accurately identify subglacial lakes using machine learning. This study successfully leverages patterns in geophysical and environmental data to predict whether a given area is a subglacial lake or not. Here we show that a supervised Machine Learning (ML) approach, K-nearest Neighbors Classification, trained on diverse datasets to effectively predict whether a point is a subglacial lake with high accuracy (80% in initial testing). With this model, we explore a set of lake candidates to predict their classification as lake or non-lake to update the current inventory of subglacial lakes for better estimates of the amount and spatial distribution of subglacial water. This project is just the tip of the iceberg for using ML techniques in identifying subglacial lakes. By using ML techniques in subglacial research we can enhance our understanding of subglacial hydrology and what features, like basal friction or hydro-potential, have the greatest effect on it.

#87 Investigating The Impacts of Artificially Rough Bed Topography On Antarctic Subglacial Flow Routing

Author(s): Mia Jungman, Junior, Geophysics
Mentor(s): Wilson Sauthoff

Subglacial flow routing is an important aspect of ice sheet dynamics as it influences basal sliding, ice flow velocity, and the formation of subglacial lakes. Modeling subglacial flow routing relies on predicting hydropotential surfaces. In glaciology, the hydropotential surface, or hydraulic head, represents the gravitational potential energy of water within subglacial drainage systems–this calculation is based on ice sheet elevation and bed topography measurements. Antarctic bed topography measurements suffer from low spatial resolution across the continent. Extensive interpolation between known measurements creates an unrealistically smooth realization of bed topography that cannot accurately model large scale ice sheet dynamics. The purpose of this study is to explore the effects of adding artificial roughness to bed topography measurements. Specifically, we aim to quantify its impact on subglacial routing. The investigation involved introducing Gaussian noise to BedMachine Antarctica measurements and subsequently evaluating the changes in subglacial flow using hydrologic analysis tools. By comparing the artificial model to the original model, we investigated changes in the number of branches, number and location of outwash points, and the boundaries of drainage basins. The results demonstrate the influence of added bed roughness on subglacial flow routing models and highlights the Antarctic researchers' need for higher resolution data in order to create more accurate large-scale ice sheet models.

#88 Observing Interactions Between Ocean Currents and Surface Waves

Author(s): Jackson Krieger, Junior, Geophysics
Mentor(s): Bia Villas Boas, Gwen Marechal

The transfer of energy, heat, and mass between the ocean and atmosphere is crucial in understanding and predicting the Earth's climate. In the present work, we use data collected by autonomous platforms, called Saildrones, during NASA's Sub-Mesoscale Ocean Dynamics Experiment (S-MODE), to better understand the interactions between ocean currents and surface waves. We analyze Saildrone observations of surface temperature, salinity, currents, winds and waves to identify fronts with the goal of understanding the underlying small-scale dynamics and its impact on the spatial gradients observed in the wave field.

#89 Biochar and Soil – Impacts on Hydraulic Conductivity and Biochar Mobility

Author(s): Jude Lowe, Sophomore, Geophysics
Mentor(s): Brandon Dugan

Bio-char is charcoal that is intentionally produced for different uses such as agriculture and carbon sequestration. Biochar addition to soil has agricultural benefits because it can increase water and nutrient delivery to plants. These benefits, however, are only valuable as long as the biochar remains in the soil. To improve assessment of benefits, we are conducting hydraulic conductivity experiments of different biochar-soil mixtures, measuring how hydraulic conductivity varies with different biochar concentrations and over time as biochar migrates, and developing novel techniques to quantify how much biochar is migrating. As we established our experimental methods, we directly observed biochar mobility. With our experimental method now established, we are continuing experiments to address how and why hydraulic conductivity changes. In parallel we are designing a new experimental tube where we can simultaneously measure magnetic susceptibility and hydraulic conductivity. We anticipate the magnetic susceptibility will help inform quantitative measures of how the biochar moves through the sediment. By determining how biochar moves in saturated sediment using magnetic susceptibility, we will provide an important tool for constraining the temporal benefits of biochar amendment to soils.

HUMANITIES, ARTS, AND SOCIAL SCIENCES

#90(O) Policy Recommendations for an Equitable Energy Transition in Denver

Author(s): Fischer Argosino, Senior, Mechanical Engineering
Mentor(s): Justin Latici

According to the nonprofit Energy Outreach Colorado (EOC), one in four households in the Centennial State struggle to meet their energy needs. This number will only rise as more utility companies invest in clean energy technologies because this drives the cost of energy higher each year. Although the clean energy transition is essential in the fight against climate change, we must ensure that this does not exacerbate inequities concerning energy access. One important program that addresses this issue is the Low-income Energy Assistance Program (LEAP). While LEAP has improved the lives of thousands by offsetting their energy burden, it has the potential to create a larger impact. During 2022-23 season, the overall LEAP denial rate was 35%; however, in Denver County, the denial rate was 44%. This is striking because Denver County has the most families living below the poverty line in Colorado. Based on statistical results contextualized by the experiences of subject matter experts, this project recommends changes to the LEAP Program's income qualification criteria along with restricting the program's review process to county administrators. These conclusions were reached by performing a statistical analysis on LEAP data provided by the State of Colorado, Census

Data, and the Energy Information Administration to identify areas of improvement in the program that may enable more families to access these benefits. The results of this data are also supported by interviews with leading researchers in energy equity, social workers, Denver-based energy access advocates, and LEAP administrators.

MECHANICAL ENGINEERING

#91 Muscle Excitation During the Five Times Sit-To-Stand Test Is Affected By Age

Author(s): Claire Beebe, Senior, Mechanical Engineering
Mentor(s): Anne Silverman, Michael Miller

Each year, 28-35% of people 65 and over have at least one injurious fall, which can limit mobility and reduce quality of life. The Five Times Sit-To-Stand (5xSTS) is a clinical evaluation of muscle strength and fall risk. However, the outcome of this assessment, time to completion, does not reveal muscle coordination or movement during the task. Evaluating muscle coordination is important to guide treatment and reduce fall risk. Thus, we compared lower limb muscle excitation with electromyography in younger and older adults during 5xSTS. Twenty-two (11 younger and 11 older) healthy adults completed a 5xSTS trial where they rose from a seat to a standing position and returned to the seat five consecutive times as quickly as possible. We compared integrated electromyography values for the leg and low back muscles as well as hip, knee, and ankle joint moments between groups with an unpaired t-test. Older adults required greater muscle excitation for the gluteus medius ($p=0.025$), lumbar paraspinals ($p=0.014$), rectus femoris ($p=0.002$), vastus lateralis ($p=0.011$), and tibialis anterior ($p=0.038$). Older adults took a similar amount of time to complete 5xSTS ($p=0.473$), indicating muscle compensations in this group. Older adults had similar or lower joint moments when compared to younger adults. Thus, older adults generated similar muscle forces as younger adults during 5xSTS, but required greater muscle excitation to achieve these muscle forces. Muscle excitation changes may affect energy cost and fall risk during sit-to-stand with aging. Understanding these changes can aid in developing rehabilitation treatments and muscle strength benchmarks.

#92 3D Backpack and Torso Motion are Regulated on Walking Slopes

Author(s): Kagan Giltinan, Senior, Mechanical Engineering
Mentor(s): Anne Silverman

Military personnel carry heavy backpacks while walking on different terrains. Backpack attachment properties like stiffness and damping change the movement of the backpack and affect energetic cost, forces experienced by the wearer, and gait stability. However, whether use of current, military style hip belts affect the motion of the backpack or the wearer across different terrain is unclear. Thus, the purpose of this study was to characterize the relative backpack motion for multiple walking slope conditions. Participants walked on downhill, level, and uphill slopes. They wore backpacks using only the shoulder straps or with the hip belt secured. Optical motion capture tracked markers on the full body as well as the backpack frame. Maxima and minima of backpack-torso displacement and absolute torso displacement

were calculated and the difference between sequential maxima and minima were used to obtain a total of five ranges for each participant and condition. Absolute torso vertical and relative lateral displacements were significantly affected by slope. Backpack-torso relative vertical displacement had no significant differences for pack or slope. The vertical displacement results suggest that the participants are modifying their gait across walking slopes to regulate relative backpack-torso motion, even though torso absolute motion varied between these conditions. The torso absolute displacements remained consistent for all walking slopes, but the relative lateral motion significantly differed. This suggest these same adaptations were not made trying to limit lateral displacement, which may indicate lateral displacement is less influential to variables such as peak vertical forces, walking efficiency, and perceived comfort.

#93 Shoulder Pressure Area, But Not Lateral Symmetry, is Influenced By Hip Belt Use During Heavy Load Carriage

Author(s): Madeline Inge, Senior, Mechanical Engineering
Mentor(s): Anne Silverman, Jordan Sturdy

The focus of my research project is to quantify the influence a hip-belt backpack attachment has on the symmetry and magnitude of shoulder loading when a military pack load exceeds 40 percent of the carrier's body weight. Musculoskeletal injury to the lower back resulting from heavy load carriage (25–45 kg) is common among military service members [1]. Heavy loads can cause high tissue strain on the shoulders, impairing neural conduction and reducing motor function [2]. Implementing a hip-belt is intended to offload some of this injury-inducing pressure and transfer it to the pelvis, but the efficacy of the hip belt in achieving this goal remains unclear. We evaluated 12 military service member volunteers who wore a helmet and body armor (~6.5kg) and carried a backpack in two attachment conditions: (1) entirely shoulder borne, and (2) with a hip-belt attachment, all totaling 40% body weight. Participants walked at three slope conditions (10° downhill, level, and 10° uphill) at 1.15 m/s for each backpack condition. Pressure on both shoulders was analyzed for a 5-second time frame in each condition and compared statistically with a paired t-test (a=0.05). Results demonstrated that walking with the hip-belt engaged compared with the shoulder borne-only backpack resulted in ~9 kPa smaller peak shoulder pressure on average across slope conditions. Additionally, wearing a hip belt also significantly affected the area of pressure, with an average of 22 cm2 smaller area of active pressure compared with the shoulder-borne condition across slope conditions (p = .001). Finally, shoulder pressure asymmetry was not significantly affected by hip belt use; however, results indicate that both hip belt and shoulder-borne conditions had ~20% asymmetry averaged across slopes. This research indicates that wearing a hip belt when carrying a heavy backpack will reduce shoulder pressure and area of pressure, regardless of walking terrain, suggesting reductions in tissue strain and discomfort.

#94 FEA Ankle Model To Analyze Ligament Load And Preventative Braces

Author(s): Maximalian Kephart, Senior, Mechanical Engineering
Mentor(s): Anthony Petrella, Mykola Mazur

In the United States 25,000 ankle sprains occur every day where inversion sprains make up 80% of all ankle sprains. Inversion sprains structurally have the potential to affect three ligaments: the anterior talofibular (ATFL), calcaneofibular (CFL), and posterior talofibular (PTFL). The ATFL is the weakest ligament by far where 70% of lateral ankle sprains only involve this ligament. An ankle brace's goal is to take on the majority of the structural load that would be otherwise put onto the ligaments; moreover, in inversion sprains the brace needs to specifically protect the ATFL. The purpose of this study was to develop an FE model that uses external 3D scans to quantify the effectiveness of different ankle brace designs by analyzing the forces along the ligaments caused by an inversion sprain. Four simulations were analysed, three of which used a 23 N-m moment applied on the ankle, foam brace, and plastic brace while the fourth simulation used a 46 N-m moment on the plastic brace. After applying a 23 N-m moment onto the ankle, the foam brace reduced the load on the ATFL by 51% and further reduced by the plastic brace by 80%. The significance of this study is the development of an FE model that can be applied to individual users to aid the design of custom fitting ankle braces while measuring this design's effectiveness in protecting the ATFL, CFL, PTFL, and preventing ankle inversions.

#95 Autonomous Lunar Landing Site Preparation - Testbed Gantry Components

Author(s): Thomas Lee, Junior, Mechanical Engineering
Mentor(s): Andrew Petruska

Mines has been contracted by NASA as part of the Lunar Surface Technology Research – Autonomous Site Preparation: Excavation, Compaction, and Testing (LuSTR-ASPECT) Project, whose ultimate goal is to design and prototype an autonomous robot that can prepare a spacecraft landing location on the Moon. Once constructed, the robot will require a simulacrum of the Moon's surface for testing purposes. In addition to a large "sandbox" containing a lunar regolith simulant, the testing environment includes an XY gantry system to carry the robot's power cord during the testing period. During this research period, we utilized SOLIDWORKS computer aided design software to design two major components of the gantry system – the "truss movers" and the "cart". The "truss movers" are positioned under the gantry's crossbeam, carrying it along a set of V-tracks and enabling translation on the X-axis. The "cart" carries the robot's power cord and the gantry's electronic hardware and rolls along the length of the crossbeam, enabling translation on the Y-axis. Validation of the designs will be executed by building small-scale prototypes to test their performances and manufacturing processes. Completion of the components' designs has furthered the overall progress of the testbed, and construction will soon begin in the Earth Mechanics Institute.

#96 Multi-Alloy Additive Manufacturing

Author(s): Turner McCutchan, Junior, Mechanical Engineering
Mentor(s): Joy Gockel

In this research project, additively manufactured tensile and torsion specimen geometries were designed and tested to evaluate the location of failure. These specimens will eventually be used to test the interface properties of multi-material components. Ensuring failure at the midpoint/interface is crucial for multi-material applications, as failure must occur at the interface in order for the interface strength to accurately be characterized. To induce failure at the interface/midpoint, a variety of specimen geometries were created which reduce the area of the specimens to be the smallest at the midpoint. This will lead to the highest stress occurring at the midpoint and therefore failure of the specimen. Specimen geometries will be tested in both tension and torsion to induce a variety of loadings and failure types. Theoretically, both reduced-area geometries should force failure directly at the midpoint as the smallest cross-sectional area exists there. Testing will show whether these geometries can repeatedly force failure at the midpoint. Successful results can be extended to test the interface strength of multi-material parts, enabling localized performance and customizable material properties.

#97 Prevention of Ankle Sprain Using Active Brace Design Components

Author(s): Shayn McHugh, Senior, Mechanical Engineering
Mentor(s): Anthony Petrella, Mykola Mazur

Ankle sprains are a common cause of activity limitation within the civilian population, and they are an important cause of reduced warfighter readiness among US armed forces. Most ankle braces are completely passive, meaning that they are unpowered and the structure of the braces itself provides all of the support. The aim of this study was to develop a lightweight, efficient actuation or damper mechanism for efficient functional sprain prevention along with passive elements of our ankle orthotic device. The study is currently focusing on magnetorheological (MR) fluid dampers as a sprain-prevention component of the brace, and developing an MR fluid damper prototype.

#98 Design of a Passive Ankle Brace Leveraging Advanced Cellular Constructs with Graded Compliance

Author(s): Delaney Meek, Senior, Mechanical Engineering
Mentor(s): Anthony Petrella

Approximately 80% of all sprain cases are inversion sprains of the ankle, which is around 23,000 sprain per day [1]. Current orthoses designs present limitations in movement and discomfort from the brace. The goal of this project is to develop an ankle brace which will adhere comfortably to the user while being able to deflect with normal plantarflexion and dorsiflexion. The goal of this research is to provide an ankle brace that restricts minimal movement while still maintaining support to resist inversion, and fits the user comfortably. One method of brace fabrication considered was molding soft thermoplastic to the user but, this material was too rigid, and could cause irritation. To increase adherence, the brace will be 3D printed with a CAD model made from a scan of the user's foot taken with the Einscanner. In order for the brace to deflect with normal plantar flexion and dorsiflexion, the section of the brace covering the calcaneofibular ligament is made of a hexagonal lattice pattern. The brace was printed in the ADAPT lab using TPU on the Stratasys F170 printer. In this project, multiple forms of brace fabrication were considered until choosing additive manufacturing. The material used allows for deflection in the brace and reduces skin irritation.

This project showed the capability of additive manufacturing for designing braces that can fit their users proficiently. Next steps for this project should include printing of more complex lattice structures, including structures with non-uniform cell size. In addition to this printing, the braces should be tested for inversion resistance, and in conditions that simulate walking and running.

#99 Understanding and Predicting Ankle Sprain Through Machine Learning

Author(s): Jordan Szigeti-Larenne, Junior, Mechanical Engineering
Mentor(s): Anthony Petrella

Ankle injury is a fundamental and recurring issue in high impact activity that affects athletes, military personnel, and everyday people. Current attempts at ankle injury mitigation look towards passive devices that simply support the ankle through bound structure built through the device. The goal of this study was to identify the risk factors and indicators that are actively associated with ankle sprain, implement them into a machine learning algorithm, and establish a program that could significantly predict ankle sprain. The currently understood risk factors were distinguished through previous research papers and were used as key features for the machine learning algorithm. Based on these features machine learning algorithms were used to predict ankle sprain. This preliminary research sets the stage for future research into wearable devices that could be implemented into a passive ankle brace and predict sprain while in motion. This prediction could then be implemented into active devices that will increase the stiffness of the brace only when sprain is likely.

#100 Symmetry in Ground Reaction Forces During Step Downs

Author(s): Ava Watson, Junior, Mechanical Engineering
Mentor(s): Anne Silverman, Jordan Sturdy

Stepping down from a surface, such as a curb or stairs, is a daily experience that is critical for independence and community integration. An estimated 65-74% of the population demonstrates footedness, which may affect how people step down. The purpose of this study was to examine the symmetry of the ground reaction forces of a step-down action and its possible relation to footedness. Studying this link will improve understanding of gait and footedness, which has implications for expanding to mobility-impaired populations. Three participants (1M/2F, age 25.0±4.6 years (mean±SD), height 67.3±1.3 inches, and body mass 137±16.7 lbs) completed a step-down action from a 10 inch (25.4 cm) high stool onto in-ground force plates (AMTI, 2000Hz) to record ground reaction forces. Footedness of each participant was determined with the Lateral Preference Inventory questionnaire. The task began with both the participant's feet planted on the stool. The participants were instructed to step down with either their right or left foot and continue walking to produce a fluid motion that mimicked stepping down in their daily life. The participants completed this task a total of 5 times for each foot. The ground reaction forces were exported to MATLAB to quantify the maximum vertical, propulsion, and braking forces on each foot. The ground reaction forces for each participant were compared between their dominant and non-dominant foot as well as

other participants' dominant and non-dominant feet respectively. These comparisons will provide insight into the symmetry of the step-down action and its relationship to footedness.

METALLURGICAL AND MATERIALS ENGINEERING

#101 Investigating the Impact of Processing Parameters on the Mechanical Properties of 3-D Printed Parts Produced by Vat Polymerization

Author(s): Hanna Bakula, Senior, Chemical and Biological Engineering
Mentor(s): Jeffrey King

Consumer grade vat polymerization printers can affordably produce high resolution plastic parts for prototyping and functional application. These printers are readily available, along with a wide range of possible resins. However, there is limited information available on how various print parameters (print orientation, build plate location, exposure time, cure time, et al.) impact the mechanical properties of printed pieces. For this project, an AnyCubic Photon Mono 3D printer created printed pieces for mechanical testing. A Deben Microtest micro load-frame allowed for compression, three- and four-point bend, and tensile testing to be conducted on the printed parts. Data provided from mechanical tests allowed for the analysis of the relationships between print orientation, exposure time, and cure time, and the force required to break or severely deform a piece. Future work for this project will look at continuing to establish the relationships between the various print parameters and the resulting mechanical properties of the printed products.

#102 Determining Polarity in Ferroelectric Materials Using Precession Electron Diffraction and Cepstral Analysis

Author(s): Colton Brown, Junior, Metallurgical and Materials Engineering
Mentor(s): Megan Holtz

Understanding local crystallography is necessary for understanding ferroelectric behavior in materials. Key properties to know include lattice parameters, interatomic spacings, and polarity. One tool to learn these properties is scanning transmission electron microscopy (STEM), which can measure a diffraction pattern (kx, ky) at every scan position (x, y). This allows crystallographic properties to be investigated at the nanometer scale. However, diffraction signals can contain artifacts from sample thickness and mistilt. These artifacts may be suppressed with precession electron diffraction (PED), which has the additional benefit of increasing the number of reflections in the diffraction pattern. In this work, we perform analytical calculations to assess the efficacy of using PED combined with cepstral analysis to measure polarity in lead magnesium niobate-lead titanate (PMN-PT). Taking the Fourier transform of the logarithmically scaled diffraction pattern yields the exit-wave power cepstrum (EWPC) which yields interatomic spacings in the crystal. To extract polarity, we use the imaginary component of the transform which contains the antisymmetric information, which is called the exit-wave imaginary cepstrum (EWIC). The EWIC transform is improved by having more higher-order diffraction disks, which is possible through PED. It was found that PED

improves the EWIC signal: as precession angle was increased from 0° to 0.5° to 1°, signal noise decreased and dipole moments were better resolved in scenarios with and without mistilt. These results indicate that cepstral analysis of real samples may benefit from PED.

#103 Thin Film Deposition Lab

Author(s): Jack Dorsey, Junior, Metallurgical and Materials Engineering
Mentor(s): Megan Holtz

The MnxOy family of oxides is an exciting material system for studying ionic conduction, ferroelectricity, and magnetism in thin film materials. However, several of the phases of interest are challenging to produce. Molecular beam epitaxy (MBE) is a powerful tool that allows for the precise growth of these challenging phases using varying temperature and oxidative environments. By understanding the thermodynamics of oxide formation and using epitaxial stabilization, we can grow high quality samples of each phase of the MnxOy family. Ellingham diagrams were calculated and plotted to develop growth windows for each phase. Lattice parameters and crystal structures were compared to understand the epitaxial relationships between film and substrate. Using the growth conditions and substrates found above, thin films of the MnxOy family were grown. These films were characterized by using reflection high-energy electron diffraction (RHEED) to verify crystallinity and x-ray diffraction (XRD) to characterize the phase present.

#104(O) Advanced Gas Metal Arc Welding Processes to Clad Molten Salt Reactor Components

Author(s): Xavier Fross, Sophomore, Metallurgical and Materials Engineering
Mentor(s): Jonah Klemm-Toole

There is a constant need for renewable energy sources, and the requisite technology to ensure their equitable and accessible distribution. Two very promising sources are nuclear energy and concentrated solar power. However, these methods for power generation cause extreme environments, exceeding 315 and 565 Celsius respectively. This presents a serious materials challenge to ensure safe operation of such energy sources. Nickel superalloys are a relatively new area of research, and may provide the solution to safe, cheap, and excellent materials for molten salt reactors (MSRs). These alloys exhibit excellent high temperature creep and strength as well as molten salt resistance. Haynes 244 is such a nickel superalloy, and has been tested over this project for compatibility with MSRs. This project investigated heat inputs (pulse multi-control, PMC, and cold metal transfer, CMT) as a factor affecting the physical characteristics of the deposited metal during welding. Molten salt corrosion testing will be conducted by an outside company to compare the effects of the heat input on corrosion behavior.

#105(O) In-Situ Hydrogen Quantification, Migration, and Hydride Studies

Author(s): Maddy Hoffmann, Junior, Physics

Mentor(s): Jeffrey King

Zirconium alloys are a commonly used structural material in power reactors due to their corrosion resistance, neutron transparency, and adequate mechanical properties. A high-temperature corrosion reaction between zirconium and water creates hydrogen that can migrate into the cladding. When the hydrogen concentration in the zirconium exceeds the appropriate hydrogen solid solubility limit, precipitation occurs and can cause embrittlement and premature cladding failure. This study aims to quantify hydrogen and hydride presence in various zirconium alloys leveraging the unique capabilities of neutron radiography. Non-destructive testing (NDT) of zirconium samples allows for a better understanding of hydrogen distribution and precipitation through zirconium components, allowing more accurate lifetime predictions and perhaps enabling the design of new alloys. A total of 33 zirconium alloy samples have been charged in various ways to include both homogeneous and non-homogeneous hydrogen distributions and sectioned in preparation for imaging and traditional destructive analysis. This neutron radiography-based hydrogen quantification study will enable previously inaccessible experimentation which may better illuminate the migration and precipitation behaviors of hydrogen in zirconium, giving new insight that may be leveraged to create better-performing alloys.

#106 Understanding Multi-Functional Materials Through Preparation and Characterization of Formate Perovskites

Author(s): Andrew Hope, Sophomore, Metallurgical and Materials Engineering
Mentor(s): Eve Mozur

Multi-functional materials have been studied intensively for the last few decades for their interesting, coupled physical properties, and wide variety of potential applications: including high-density multi-state digital storage and small-scale magnetic or electric field sensors. Multi-functional materials are a class of materials in which the electric dipole (positive and negative ends of the molecule) alignment, and magnetic properties are coupled . Thus, generating an electric response when the material is in a magnetic field and vice versa. However, there are few materials that exhibit this multi-functional behavior. Additionally, out of the materials that have been synthesized, many are lacking characterization data. Therefore, it is challenging to develop structure-property relationships and design principles for multi-functional materials. Our goal is to develop a framework such that we can properly engineer these materials or find a relationship between the crystal structure to the magnetic and dielectric properties.

To achieve this goal, we will make a series of these multi-functional materials to understand these structure-property relationships. Structural characterization such as x-ray diffraction will determine trends in material structure. We plan on using magnetometry and dielectric spectroscopy under applied field conditions to study the functional properties.

#107 Position Control System Development for a Lab-Scale Forging Manipulator

Author(s): Lennard Poliakov, Junior, Mechanical Engineering
Mentor(s): Kester Clarke, Albert Ostlind

A linear-rotational actuator manipulator has been developed to support lab-scale forging experiments to evaluate cogging operations with an open-die press. The robotic actuator is designed to hold a metal bar, enables rotation and translation relative to the press and affords the ability to be used in conjunction with an induction heater. This experimental capability allows for the study of path-dependent deformation sequences that can inform deformation models. Due to the significant reactionary forces during the forging operations, some deviation between intended and actual deformation paths have been observed. Python has been used to collect feedback from a rotary encoder in order to facilitate accurate deformation paths during forging. Feedback on the rotational position of the bar allowed implementation of a PID (Proportional-Integral-Derivative) controller to reduce error in positioning of the bar. The control model used was that of a Direct Current motor with an input of current and an output of angular position. MATLAB was used to tune the theoretical control system in order to determine the PID constants for the rotational control system. The angular position error observed after implementing the PID controller is on average plus or minus 5 degrees from the intended target of 90 degrees when the motor is set to its maximum speed. This error is 3 times smaller than the error observed from the system without the PID controller, which can lead to reproducible and more accurate cogging operations.

#108 Improving Conversion Cathode Reversibility Through Insertion of Nucleation Points

Author(s): Emily Stec, Senior, Chemical and Biological Engineering
Mentor(s): Eve Mozur

Lithium-ion batteries are a significant form of energy storage due to their rechargeable nature and ability to operate in ambient conditions. However, most existing rechargeable batteries have low charge capacity because electrons and ions transfer via intercalation. During intercalation, lithium ions insert into channels in the cathode material, causing the charge capacity of the cathode to be restricted to one electron per redox reaction because of available lithium site vacancies. The capacity of lithium-ion batteries could be increased by implementing the use of conversion cathodes, in which the cathode material reacts with lithium ions and electrons to completely reduce the cathode metal. Iron oxyfluoride (FeOF) is a promising conversion cathode that has the potential to move three electrons per redox reaction. However, the change in crystal structure that FeOF experiences upon discharge has led to poor reversibility during recharge. Upon cycling, the cathode material prefers to stay as a multiphase material instead of returning to the original rutile crystal structure of FeOF. This project proposes that to improve reversibility, titanium oxide (TiO_2) can be inserted into FeOF to act as nucleation points during cycling. The rutile crystal structure of TiO_2 will serve as a template for the cathode material to form its rutile phase upon recharge. After synthesizing FeOF and inserting TiO_2, the battery cell properties can be tested with electrochemical techniques to analyze improvements to capacity and reversibility.

#109 Constructing a TTT diagram for ATI 642

Author(s): Gabriel Thompson, Junior, Metallurgical and Materials Engineering
Mentor(s): Kester Clarke

Within nickel super alloys, a metal phase known as the sigma phase may develop, deteriorating the mechanical properties of the metal while removing elements such as molybdenum from the surrounding alloy, decreasing corrosion resistance. ATI642 is a nickel super alloy developed by ATI with the purpose of suppressing sigma phase formation while maintaining properties and decreasing cost. In this project, samples of ATI642 were sectioned and heat treated to identify the temperatures and related times at which sigma phase develops, with a method known as energy-dispersive X-ray spectroscopy used to identify the presence of sigma phase, and X-ray diffraction used to try and find the exact volume percent of sigma phase present. The development of sigma phase in ATI642 was found to form the fastest at a temperature between 850°C and 875°C, forming after 60 minutes, and slowing down in formation at temperatures above and below this point. Attempts to identify the exact volume percent of sigma phase present were unsuccessful, as XRD was unable to detect the presence of sigma phase due to its slow development.

#110 Machine Learning in the Synthesis of Manganese Based Intermetallics

Author(s): Bryce Walsh, Senior, Computer Science
Mentor(s): Eve Mozur

In material science, we have a large backlog of ways to make different materials, however the synthesis of a new materials is a time-consuming process of trial-and-error. Much of this time and energy is dedicated to figuring out the process to get from our initial compound to that known result. Our goal is to reduce the time intensity of this by discovering trends in the methods of preparing manganese based intermetallics. Experimental features include reaction times, annealing temperatures, and annealing cycles. Unfortunately, there is no obvious trend present between the initial compounds and the steps needed to reach our manganese materials. In the present study, we implemented machine learning techniques to help us identify if there are underlying trends. We tested using interpretable models (Random Forest, Support Vector Machine, Statistical Methods) as well as uninterpretable models (Deep Neural Net and K-Means). As many of the experimental datasets have limited details, we were often forced to train on a small subset of the data especially when using multiple parameters. Initial results point to the existence of a correlation, however more work is necessary to draw a conclusion. After we find an underlying trend for manganese-based materials, we plan to apply similar techniques to a broader range of situations in the synthesis of materials.

#121 Augmentation of the Integumentary System

Author(s): Anna Pedercini, First Year, Chemistry
Mentor(s): Terry Lowe

A relevant topic among athletes who deal with repeated bodily impacts is how injury can be best be prevented. Most sports require the use of some kind of gear to mitigate the expected impacts but still face long-term damage to the impacted area. The epitome of this is dancers who commonly participate in floor work where, without knee pads, they risk severe damage and bruising of the patella. Although not commonly known by non-dancers, current kneepads on the market tend to be bulky, expensive, and inadequate to mitigate injury. Previous and current dancers have noticed a trend in the average kneepad on the market: too thin/bulky, tight/loose, and stiff/soft. The Lowe Lab is currently researching how to improve the design of knee pads for dancers to mitigate injury and have the pad essentially act as augmented skin. A significant player in the kneepad is the vesicle that will surround the components inside. Through literature analysis and review, we have found many issues in current vesicles used and trends as to why they are still in use (mainly cost). And we have found that through the use of the correct materials, we can make the vesicle thin (2-4 mm) and still abrasion-resistant while potentially contributing to the impact mitigation- typically only a property of the contents of knee pads.

#122 Machine Learning-enabled Medical Device Materials (MLMDM)

Author(s): Kaitlyn Betz, Senior, Quantitative Biosciences and Engineering
Mentor(s): Terry Lowe

Machine learning (ML) methods can provide exceptional enhancements to both the performance and manufacturing of medical device materials. Enhanced materials and methods to make them can transform medical device fabrication and healthcare. Improved quality assurance and real-time error detection become feasible with ML algorithms. Fabrication steps can be implemented with greater precision, efficiency, and waste minimization. Production parameters can be fine-tuned, including the prospect of tailoring materials and devices to individuals, enabling personalized care. We highlight three examples of ML technologies under development in our Transdisciplinary Nanostructured Materials Research Team (TNMRT). We are developing Convolutional Neural Networks (CNN) to develop 1) antimicrobial copper surface nanostructures, 2) ferrofluid methods to detect magnetic phases in stainless steel, and 3) optical image analyses to predict alloy formability to fabricate surgical devices.

#123 Ambient Oxidation Dynamics of Copper Antimicrobial Surfaces

Author(s): Emmelia Ashton, Senior, Metallurgical and Materials Engineering
Mentor(s): Terry Lowe, Daniela Hirsch

In recent years, increased resistance of pathogens to traditional antibiotics has mounted serious health concerns. The development of novel, improved, and non-selective antimicrobial agents is necessary to combat the further spread of infectious disease and protect public health from antibiotic resistant superbugs. Recent advancements in understanding naturally biocidal surfaces have led to the development of nanopatterning techniques aimed at enhancing the antimicrobial properties of metallic substrates like copper. Copper possesses natural antimicrobial activity which can be enhanced by creating nanoscale surface features. Leveraging the heightened biocidal effect of copper substrates holds promise across various applications to address the escalating challenges posed by bacterial resistance and the proliferation of infectious diseases. However, despite its efficacy and common use in antimicrobial applications, copper is susceptible to oxidation in ambient environments. To understand how copper surfaces change when used in biocidal applications, surface oxide thickness on four copper substrates was periodically measured using ellipsometry to

characterize the growth of cuprous oxide under ambient conditions.
Such analysis aims to quantify oxide layer thickness and delineate the growth kinetics of cuprous oxide under ambient conditions, providing crucial insights into the response of copper substrates to ambient environmental factors. Understanding surface oxidation dynamics is pivotal in evaluating the long-term antimicrobial efficacy of copper and optimizing its applications in combating infectious diseases.

MINING ENGINEERING

#111 Generative Artificial Intelligence for Enhanced Situational Understanding in Virtual Reality

Author(s): Jordan Lam, Sophomore, Computer Science; Danny Nguyen, Sophomore, Computer Science
Mentor(s): Sebnem Duzgun, Doga Demirkan

In various scenarios, like educational settings and serious gaming environments, the importance of spatial reasoning of the surrounding environment is essential. Virtual Reality (VR) and the generative artificial intelligence (ChatGPT API's) capabilities provide a user-friendly approach to enhancing situational awareness and facilitating real-time communication. My research aims to integrate the ChatGPT API into VR environments to develop capable assistants who can contextually explain the user's surroundings. This integration allows users to interact with the assistant through text or speech and receive instant information and guidance based on their environment or actions. Through preliminary experimentation, it has demonstrated the efficacy of generative AI in VR for its potential applications in transforming education and serious gaming.

#112 Correlation of Electrical Resistivity Profiles and Soil Properties at Mine Waste Sites

Author(s): Frances LeDuke, Sophomore, Geology and Geological Engineering
Mentor(s): Rennie Kaunda

Environmental contamination due to legacy mining activities is a serious global challenge. In this study, 2D electrical resistivity surveys were conducted at sites contaminated with mine waste in Zambia. Legacy mining operations in Zambia have created heavy metal pollutants which exist in waste rock (tailings), soil, as well as local surface water bodies. The contamination poses a serious health risk to the environment and local communities. Subsurface characterization of the contaminated sites using geophysical methods can help with planning for remediation strategies by providing a conceptual model of the extent and intensity of the contamination. The specific aim of this study was to generate 2D electrical resistivity profiles and to investigate the correlation between geophysical subsurface profiles and soil properties at the contaminated sites. In addition, this study aims to assess subsurface contrast between remediated and non-remediated areas of contaminated sites. The study reports geophysical investigations conducted at various sites contaminated with heavy metals in Kabwe, Kitwe, and Mufulira. Preliminary results show distinct resistivity profiles between

remediated and non-remediated areas in addition to a correlation between resistivity values and moisture content. Results from this study have potential of being useful geophysical proxies for characterizing sites contaminated with mine waste.

PETROLEUM ENGINEERING

#113(O) Hydrogen Storage in Subsurface: Influence of Rock and Geofluid Chemistry

Author(s): Ryan Carbajal, Senior, Quantitative Biosciences and Engineering; Alfred Snodgrass, Senior, Petroleum Engineering
Mentor(s): Parisa Bazazi

We study the viability of subsurface environments for hydrogen storage, focusing on the critical influence of rock and geofluid chemistry. Recognizing the increasing demand for sustainable energy solutions, hydrogen storage presents a promising avenue. However, the interaction between hydrogen and geological formations is complex and pivotal for storage efficiency and safety. We focus on the effect of rock mineralogy (silicate and carbonate), and geofluid composition (salinity) on hydrogen storage and retention in subsurface storage. We measured the hydrogen-solid surface-fluid contact angle and surface tension between hydrogen and fluid and at different pressure using a high pressure-high temperature drop shape analyzer set-up with the aim to identify optimal conditions for hydrogen storage. The findings offer insights into enhancing storage capacities, minimizing environmental impacts, and ensuring long-term stability, contributing to the development of reliable and environmentally friendly hydrogen storage solutions.

#114 Feasibility Analysis of Deep Geothermal Energy Production from Sedimentary Reservoirs for Electricity Generation

Author(s): Tony Salgado-Chami, Sophomore, Petroleum Engineering
Mentor(s): Dr. Luis Zerpa

The Agenda for Sustainable Development, officially adopted by the United Nations in 2015, emphasizes the importance of aligning with its sustainable development goals (SDGs) to uplift communities while protecting the environment. Geothermal energy production, which involves drilling wells deep into the crust of the Earth to extract hot water or steam, significantly contributes to several of these SDGs. Specifically, it supports Affordable and Clean Energy (SDG 7), Climate Action (SDG 13), and Industry, Innovation, and Infrastructure (SDG 9), with many other goals indirectly benefiting as well. However, the competitiveness of geothermal energy production is often hindered by the low quality of local reservoir rock; electricity generation has been traditionally limited to areas with atypical geological features near the surface, such as magmatic activity or ideal hydrothermal circulation. As a result, regions with more typical geologies must drill deeper to achieve comparable production temperatures and enthalpies. This project aims to assess the economic viability of geothermal energy production from deep sedimentary wells through a comprehensive literature review and the development of a computational model for a standardized geothermal power plant. It seeks to optimize electricity generation for generalized deep sedimentary wells and compare energy pricing with

established, traditional producers. Ultimately, this research aims to accelerate progress towards achieving the SDGs and fostering a more sustainable and equitable future by making geothermal energy as feasible and economically practical as possible.

PHYSICS

#115 Monte Carlo Modeling of sub-keV Backgrounds in Superconducting Tunnel Junctions from Gamma-Ray Interactions for SALER@FRIB

Author(s): Keith Borbridge, Senior, Physics
Mentor(s): Kyle Leach

The new Superconducting Array for Low-Energy Radiation (SALER) experiment at FRIB aims to directly embed short-lived isotopes in superconducting tunnel junction (STJ) sensors to measure nuclear recoil energies from weak decay as a search for BSM physics. At these eV-scale energies, small energy depositions from simultaneous higher-energy events (since as gamma rays) generate backgrounds which are important to understand. I will present the first Monte Carlo modeling using the test case of 137Cs decays where a 662 keV gamma-ray is emitted and deposits small energies in the silicon substrate of the STJ as a critical first step towards background characterization for SALER@FRIB.

#116 Classifying Pulse Shapes from Superconducting Tunnel Junctions for the BeEST Experiment

Author(s): John Taylor, Senior, Physics
Mentor(s): Kyle Leach

The Beryllium Electron capture in Superconducting Tunnel junctions (BeEST) experiment aims to detect physics beyond the Standard Model by measuring atomic recoils from the electron capture decay of Beryllium-7 (Be-7). The experiment utilizes superconducting tunnel junction (STJ) sensors to measure the daughter recoil kinetic energy spectrum to search for neutrino-coupled Beyond Standard Mondel physics. This work presents systematic studies that aim to distinguish between events occurring in the top and bottom electrodes of the STJs to search for the presence of a line-splitting artifact that could mimic a heavy neutrino signal. This is accomplished by analyzing the rise and fall times of the electrical pulses generated by the nuclear decays. Two primary techniques, 10-90% Rise Time Analysis and Charge Integration, are employed to investigate the pulse characteristics. While the former exhibits challenges in noise and pile-up events, the latter reveals a clear separation in the data, indicating a splitting effect caused by the STJ detector or the data acquisition system. The study proposes further investigation into the segregation observed and explores alternative methods for event separation.

#117 Identification and Analysis of Two-Pixel Correlated Events in Beest Phase-III Data

Author(s): Amii Lamm, Senior, Physics
Mentor(s): Kyle Leach

The Beryllium Electron Capture in Superconducting Tunnel Junctions (BeEST) experiment measures Lithium-7 atomic recoils from the electron capture decay of Beryllium-7 as a precision search for neutrino-coupled BSM physics. Following the single-pixel demonstration in Phase-II, Phase-III uses a 6x6 grid of superconducting tunnel junction (STJ) detectors, allowing us to analyze spatial correlations and simultaneity between devices. Due to the sensitivity of the detector, there are external events that must be identified and filtered out for the creation of the final Phase-III limit. In this talk, we present a systematic analysis of two-pixel correlated events for their location, time, energy and pulse shape to identify anomalous events and hypothesize their origins. By examining the shape and occurrence of these events, we can understand and reduce systematic uncertainty in our data and contribute to the design of the Phase-IV detector array.

#118 Fluorescent Point Tracking for Optical Encoding in Near-Field Ptychography

Author(s): Veronica Masztalerz, Junior, Physics; Nabeeha Mubeen, Sophomore, Physics; Beau Selman, Junior, Physics
Mentor(s): Dan Adams

Ptychography is a phase sensitive microscopy technique that utilizes scattered light patterns to image an object. To perform ptychography, an optical stage is employed to shift an object relative to a laser, often in hundreds of discrete positions. Keeping track of this motion involves a system of encoding the stage's position at each shift. This research focuses on optical encoding by tracking the motion of a fluorescent point adjacent to the stage. By imaging the fluorescent point at each position along with computing a convolution with prior positions, information about the fluorescent point's relative position is calculated. Thus, the difference between highest-intensity positions at each stage motion represents the length traveled by the stage, effectively encoding its movement.

#119 Reconstructing Ultra-High-Energy Particle Cascades with Deep Learning Methods

Author(s): Nathan Woo, Junior, Computer Science; Zhuoyi Wang, Junior, Computer Science
Mentor(s): Eric Mayotte, Sonja Mayotte

Ultra-high-energy cosmic rays are single atomic nuclei from other galaxies and the most energetic phenomena known to humankind. In observing these and using them to increase our astrophysical understanding, two properties are of key importance: the particle's energy and its mass. When one of these particles strikes the top of the atmosphere, they are destroyed and create a high-energy particle cascade which can reach 10 billion particles in size. Here, we present a new machine learning method to maximize the amount of information that can be extracted on the mass of the ultra-high-energy cosmic ray. We find that a neural networks such as a convolutional neural network can improve the mass prediction of ultra-high-energy cosmic rays, with a proton-iron merit factor of 9.81, three times better than traditional solutions. The extra precision on mass reconstruction for these cosmic rays can lead to a revolution on the quality of astrophysics performed with current ground-based observatories, and displays the usefulness of machine learning techniques in astrophysics.

#120 Degradation of Type-1 Collagen By Coronavirus Protease 3clpro

Author(s): Gabe Ibanez, Junior, Quantitative Biosciences and Engineering
Mentor(s): Susanta Sarkar

Patients infected by coronavirus, SARS-Cov-2, often show severe structural damage to organs. Since collagen is the primary component of structural scaffolds that maintain the integrity of tissues and organs, we studied whether coronavirus protease 3CLpro can degrade collagen, with a specific focus on type-1 collagen. We purified recombinant 3CLpro using an E. coli-based purification method and tested its effect on type-1 rat tail collagen. We incubated type-1 collagen with 3CLpro in a 1:5 ratio for 48 hours at 37 oC, the normal human body temperature, in phosphate-buffered saline (PBS) buffer. We tested the protein profile using gel electrophoresis. Our preliminary results suggest that 3CLpro degrades type-1 collagen in a pH-dependent manner with the maximum effect at pH 7.0. In contrast to discrete bands observed for collagen degradation by human matrix metalloprotease-1 (MMP1), 3CLpro appears to degrade more non-specifically. There are very few enzymes that can degrade type-1 collagen, and as such, the degradation of collagen by 3CLpro will have a significant impact on therapeutic approaches and mechanistic understanding of collagen.

NOTES