2M

McNair Session - From Chaos to Origami: Advances in Math, Physics, Chemistry and Engineering

Session Moderator: Therese Mar, OMAD and Department of Environmental and Occupational Health Sciences

MGH 288

3:30 PM to 5:15 PM

* Note: Titles in order of presentation.

Examining Chaos in a Dynamical System: The Double Pendulum

Brian Nguyen, Senior, Applied Mathematics, Univ New Hampshire
McNair Scholar
Mentor: John Gibson, Mathematics, University of New Hampshire

Periodic orbits provide an underlying structure to chaotic attractors, which provides order and low-dimensionality to complex, chaotic systems. The trajectory of chaotic systems proceeds to infinity for an arbitrary initial condition; for this reason, periodic orbits are useful as a finite set of finite mathematical objects to characterize the infinite, complex behavior of a chaotic system. In particular, the mathematical framework of chaos, chaotic attractors, and unstable periodic orbits allow for a new understanding of self-organization in complex physical systems like turbulence. In this study periodic orbits as an organizing principle will be examined in the Lorenz system and the double pendulum system. This study will find the unstable, periodic orbits of the Lorenz system and the double pendulum system using Newton's method. The expected results of the study are that periodic orbits of both systems will both be found. This study presents an opportunity for an understanding of chaotic behavior which will lead to engagement with the current research on turbulence.

Homotopy Type Theory and the Foundations of Mathematics

Jordan Leoron Charles Brown, Junior, Mathematics (Comprehensive)
McNair Scholar
Mentor: James Morrow, Mathematics

We investigate recent developments in the foundations of mathematics, particularly homotopy type theory, to determine their viability as foundations of mathematics. Related foundations such as Martin-Löf type theory, topos theory, and category theory are also discussed. We evaluate the possible benefits of a type-theoretic formulation of mathematics and the nature of constructive axiomatic foundations. The research involves a review of the existing literature in these areas and a comparative analysis of the methods used across frameworks. This research is the first step towards the development of languages easily used by computers and mathematicians which incorporate the power and flexibility of non-standard deductive procedures.

Hydroxyl Radical Scavenging Rate Constants for Solid Phase Mineral Surfaces in Oxidative Treatment Systems

Constance Green, Senior, Molecular Biology, East Central Coll
McNair Scholar
Mentor: Klara Rusevova Crincoli, R.S. Kerr Environmental Research Center, National Research Council
Mentor: Scott Huling, R.S. Kerr Environmental Research Center, USEPA

Advanced oxidation treatment processes involve powerful and indiscriminate radical intermediates, including hydroxyl radicals (•OH) and sulfate radicals (SO4-•). Inefficiency in radical-driven treatment systems involves scavenging reactions where radicals react with non-target species in water and solids. Radical scavenging studies have been focused on soluble scavengers in the water and have not assessed radical scavenging by solids which are also present in oxidation treatment systems. The objective of this study was to quantify radical scavenging by solid surfaces. •OH were produced in iron (Fe)- and UV-activated hydrogen peroxide (Fe-AHP, UV-AHP) systems where the loss of rhodamine B (RhB) dye served as an indicator of •OH activity. The basis used to estimate the •OH surface scavenging rate constant (k≡S) were comparisons of treatment results between simple solids-free oxidation systems and more complex systems containing mineral solids. The solids-free system was based on Fe-AHP and UV-AHP reactions; the solids-amended systems were identical but contained different mineral species. Therefore, differences in the loss of RhB were attributed to •OH scavenging by the solid surfaces in the Fe-AHP and UV-AHP treatment systems. Alumina (Al_2O_3), silica (SiO_2), and montmorillonite ($Al_2H_2O_12Si_4$) (MMT) are solid minerals found in soil and aquifers. These minerals were used in this study to assess the solid surface scavenging rate constants. Preliminary results in the Fe-AHP system indicated that k≡S for silica (2.85×10^6 1/m$^2\times$s) was not statistically distinguishable from alumina (3.92×10^6 1/m$^2\times$s). k≡S values in the UV-AHP system for silica (4.50×10^6 1/m2$\times$s) and alumina (7.45$\times$106 1/m2$\times$s) were greater than estimates in the Fe-AHP system and may be due to pH. k≡S,MMT ($\leq 4.22\times10^5$ 1/m$^2\times$s) was much less than k≡S for silica and alumina indicating k≡S is mineral-specific. A critical analysis suggests that radical scavenging by solid surfaces in aquifer systems is orders of magnitude greater than scavengers in the water.

High Temperature Study of the Reaction of Silicon, Titanium and Yttrium Oxides

Lizbeth Robles-Fernandez, Junior, Physics, East Central Coll
McNair Scholar
Fernando Salazar-Salas, Junior, Physics, East Central Coll
Mentor: Dwight Meyers, Chemistry, East Central University

Reactions of titanium oxide and silicon dioxide are of importance in materials used in high temperature environments. There are questions concerning the reaction of titanium dioxide (rutile) with silica. Both are important as potential materials or reaction products in thermal barrier coatings or environmental barrier coatings in combustion environments, as for example in gas turbine technologies. The extent of reaction and temperature range are important questions to answer for this chemical system. Experimental evidence would suggest that a third cation is necessary to have compound formation. Presently we are exploring the reaction of titanium dioxide with silicon dioxide with small amounts of yttrium oxide being added. Mixtures of the three oxides are being subjected to heatings at various temperatures from ca. 1200-1500C. Samples are characterized before and after heating by means of X-ray diffraction and diffuse reflectance infrared spectroscopy, transmission infrared spectroscopy, and/or diffuse reflectance UV/Vis spectroscopy as appropriate. There hasn't been any evidence of reactions between titanium dioxide (rutile) and silica. The sample will be continued to be heated at longer times and higher temperatures, and results in experiments to date at1300 C will be presented.

Low-Frequency Charge Noise in Single Electron Device

Steven Davis, Junior, Applied Physics, Calif St University San Marcos
McNair Scholar
Mentor: Justin Perron, Department of Physics, Calif St University San Marcos

Single electron devices (SEDs) are electronic devices that can isolate individual electrons along a conducting path. SEDs have potential applications in the field of metrology [science of measurement] and quantum computation. However, the devices have issues with performance, uniformity, and stability that must be addressed before these applications can be realized. To investigate these issues with SEDs, this work focuses on low-frequency charge noise, much less than 1 Hz, called charge offset drift. Previous studies have shown that the geometry of the device impacts charge offset drift. In this talk, I will describe our efforts to extend these studies, performed at 2.5 Kelvin, to millikelvin temperatures to further our understanding of these issues.

Multitransformable Leafout Origami

Kyle Johnson, Junior, Electrical Engineering
Louis Stokes Alliance for Minority Participation, Mary Gates Scholar, McNair Scholar
Mentor: Jinkyu Yang, Aeronautics and Astronautics
Mentor: Koshiro Yamaguchi, Aeronautics and Astronautics

With the increased development of space programs globally, more space probes are being funded for sample-return missions. Versatility and power limitations are some of the critical issues that these extraterrestrial sampling rovers are seeking to overcome in order to reliably deploy autonomously. Exploring the rough and unpredictable surfaces of other celestial bodies requires more adaptable and energy efficient robotics, which is what makes bio-inspired origami structures so appealing. Leaf-like origami is reconfigurable, which means that it can walk, jump, grasp, and actuate other useful motions all within the same device. Typical robots have redundant actuators and structural systems, but origami devices can build up potential energy before converting it into a mechanical motion. Due to this, rigid origami design approaches have the potential to be more compact, versatile, and energy efficient than conventional devices. Studying reconfigurable origami-based robotics can lead to devices that can be transformed into multiple configurations for various tasks. To design a versatile origami-based structure, I followed up on the research that Professor Jinkyu Yang and the members of his research group had on leaf-like origami, specifically leaf-out origami. This origami structure shows multi-transformable features. This means that the structure can be configured in a stable-stored or stable-deployed shape without having an external power supply maintaining its configuration. By finalizing the design, fabrication method, and discovering the optimized folding patterns for jumping and grasping motions, we will be able to start implementing the structure into more complex systems. Designing more structurally efficient systems may be the most practical solution we currently have to combat power and versatility limitations for autonomous space probes.