

## 490B Undergraduate Honours Thesis Presentations

The Department of Physics invites you to attend a series of short talks given by some of our senior undergraduate students in partial fulfillment of the requirements of their honours thesis course.

When: Tuesday March 6<sup>th</sup> at 10am

Where: Seminar Room, c3024

**For further information please see abstracts below.**

# Dielectric Screening in the 2D Hubbard Model

By Brad McNiven

A first attempt is made at computing the interactions of an electron system at finite temperatures using many-body theory. This task involves performing numerical integration of an infinite series of Feynman diagrams. In this work, we use numerical methods in Python and C to obtain results for the self energy of the two-dimensional Hubbard model on a square lattice for a simple correlated system of electrons. We obtain the density of states as well as the magnetic susceptibility and preliminary results for the self energy on the real frequency axis.

# Quantifying Microscale Surface Roughness using Methods of Fractal Scaling

by Brandon Collier

Is a billiard ball rough? Surely not, right? Hold it in your hands, run your fingers over it, it feels smooth and uniform. But look at that ball under a microscope and you will discover caverns, peaks, and grooves. Run a needle across it and you feel the scratching of the ball's imperfections. It turns out, the billiard ball *is* rough, but only on small length-scales. This begs the question, does a surface have one roughness value, or one roughness value for each length-scale, be it macro, micro, nano? Moreover, how would one calculate the roughness value for any *one* length-scale? Defining a single roughness value for a length-scale is non-trivial. This was the focus of my research. Using a profilometer on stainless steel samples, I researched best practices for obtaining a roughness value on the micron length-scale. A profilometer produces a line scan across a surface, indicating its height profile. When analyzing this data to find a roughness value, if the data is processed backwards as opposed to forwards, the roughness value changes. If the starting data point is shifted, the roughness value changes. If different subsets of this line scan are considered, their respective roughness values do not necessarily agree. Through heavy data analysis, what seems like a trivial experiment at first, quickly grows into something complex and fascinating. It calls into question how well we really understand our everyday surroundings - what does it *really mean* for something to be rough?

# Modelling Phase Separation of Intrinsically Disordered Proteins Into Membraneless Organelles

by Daniel Trotter

The interior of cells are densely packed with various biomolecules such as proteins and RNA. Recent studies have shown that some proteins can drive the formation of droplet-like structures inside cells by promoting a liquid-liquid phase separation. Specifically, it has been suggested that the phase separation is driven by alternating blocks of positively and negatively charged amino acids in the sequences of these proteins. In this thesis, a simple model of this phenomenon is introduced in which the proteins are represented as heteropolymers on a lattice with three different types of amino acids: positive, negative and neutral. The thermodynamic behavior of systems of such proteins with different chain concentrations are studied using Monte Carlo simulations. These simulations are used to explore whether this approach can capture a phase-separation and the character of the transition between the phases.

# Brillouin Light Scattering Studies of Natural Biotite Crystals with Differing Impurity Concentrations

by Dillon Hanlon

Brillouin light scattering experiments were performed on naturally grown crystals of biotite mica in an attempt to quantify the effects of impurities on acoustic phonon behavior. Energy dispersive x-ray spectroscopy was used to quantify the chemical compositions of biotite with differing concentrations of Fe and Mg. Brillouin spectra of these samples contained peaks due to pure transverse, quasi-transverse and quasi-longitudinal acoustic phonon modes. Analysis of these spectra permitted determination of the velocity of these modes and nine of the material elastic constants, namely  $C_{11}$ ,  $C_{33}$ ,  $C_{44}$ ,  $C_{55}$ ,  $C_{66}$ ,  $C_{13}$ ,  $C_{15}$ ,  $C_{35}$ , and  $C_{46}$ . Preliminary results suggest that the elastic properties of biotite depend on the impurity type and their concentration.

# Photoacoustic Infrared Spectroscopy: Effects of Cell Resonance on Spectra

by Marisa Dusseault

Photoacoustic spectroscopy has been used previously to study archaeological samples composed of polymorphs of  $CaCO_3$ : calcite and aragonite. Powders of calcite and aragonite were chosen to compare the rapid scan and step scan methods of photoacoustic infrared spectroscopy. The rapid scan spectra of both polymorphs matched well with results from previous works using transmission infrared spectroscopy. However, only step scans completed at specific phase modulation frequencies produced spectra that were consistent with the results from rapid scan and transmission infrared spectroscopy while a wide range of other phase modulation frequencies yielded spectra with very small signal to noise ratios from which it was not possible to identify any spectral features. This type of result has not been reported in any other works to our knowledge. We explore the possibilities of our unusual spectra being caused by resonances due to the geometry of the photoacoustic cell as well as those of the cantilever detecting the photoacoustic signal.