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RESEARCH PHILOSOPHY & PLANS

Before discussing some ideas for student projects, it is worth mentioning my philosophy of student research, which is simply an extension to my previously stated philosophy of teaching & learning. Learning is definitely not confined to the classroom, a good scholar is always improving their skills and seeking out new knowledge. Similarly, research isn't even confined to what happens in the lab or machine shop; rather, research involves presenting one's findings, attending conferences, and building a relationship with the faculty member.

With my current research students, I have tried to play the role of consultant or mentor, rather than supervisor. The students have been the ones formulating the questions and designing the apparatus. Now, I have not left them to reinvent the wheel, rather we have discussions where we share ideas. Some of their ideas (as well as some of mine) don't bear fruit, but learning from mistakes is one of the key aspects of a researcher and lifelong learner. As I see it, my mentor responsibilities are not only to share information and experiences with the students, but also to encourage them to explore on their own. There has been more than one occasion when we have attempted a technique suggested by a student, even though I suspected it would not pan out. I wanted the students to know that it is okay to occasionally fail, and not trying is much worse.

While participating in DePauw's Science Research Fellows Program, I often had the opportunity to work with some extremely talented freshmen. We would find ourselves talking about topics completed unrelated to our project. I see this as part of the mentor-student relationship. Particularly for women and underrepresented minorities, this personal connection can make a difference in their self-esteem and affect their decision whether or not to pursue a career in science. In affect, the faculty member is serving as a representative of the entire science community.

Just as courses should contain material that is of interest to students so should research projects. Particularly, when working with underclassmen I have tried to think of projects that do not require significant theoretical background, and may even be familiar to the students. Soap films, sandpiles, organ pipes, and bicycles are all examples of novel systems that contain a wealth of physics. For upperclassmen, projects that employ more advanced techniques or draw on deeper theoretical background would be appropriate. These could be anything dealing with quantum fluids, statistical mechanics, and computer modeling.

The wetting behavior of fluid on solid surfaces is of critical importance to many systems-fabrication of semiconductor devices, application of inks to paper, and even the survival of animals. One possibility for the fluid is that it completely wets the surface, forming a thick uniform film. However, if the surface tensions are altered, the fluid may not wet the surface and instead bead up like water on a waxed surface. Wetting phenomena is an issue in all systems where a fluid phase is at an interface of another fluid and solid (or between two other fluids).

For most systems the substrate is sufficiently attractive that all fluids wet the interface. However, recently several new systems have been explored that allow for wetting temperatures where the fluid goes from a wet to non-wet phase.

Most systems studied display a first order wetting transition, but it is believed that another variety of wetting was possible- continuous wetting. For these systems the film thickness is continuous across the wetting temperature. Continuous, or second order, wetting has not yet been seen in a physisorbed system. It was recently predicted that xenon on alkali metals, plated with a monolayer of gold would be a possible candidate for continuous wetting. With my experience of first order wetting and preparation of alkali metal surfaces, I believe that it would be possible to construct an experiment that would look for this new transition. I am currently preparing an application for funding that will be sent to the Research Corporation.

The experiment would require a cryostat capable of precise temperature regulation near the bulk triple point of xenon. The design and construction of such an apparatus would give students hands on experience with temperature control. The elimination of radiant heat, equilibrium time constants, and handling of cryogenic liquids would be issues that need addressing. Because surface contamination is of great concern, students would also be able to work with UHV techniques such as turbo pumps and leak detection.

Surface preparation would likely be done using evaporative techniques already used in thin film preparation. Even outside the context of the wetting experiment, the preparation and analysis of thin films could be a valuable experience for a student. Measurement of both the substrate and xenon film thickness could be done with quartz crystal microbalances. These devices allow for resolutions of fractions of a monolayer, which would be necessary at all stages of the experiment. Operation of the cryostat will require some computer programming and interface control for data collection. This experience with LabVIEW or other similar language would give a student practical experience for running future experiments.

After completion of the xenon wetting experiment, the cryostat could be used for any number of low temperature experiments. One perplexing puzzle in adsorbed films is the solid layer mobility. For warmer temperatures, when the vapor pressure is significant, the major process for mass transport is through the vapor. For situations when the vapor pressure is negligible, there are some questions as to the mechanism of transport. In my helium experiments it is seen that at low temperatures, even before the adsorbed film goes superfluid, the mass transport is very rapid. Experiments have also been performed on the kinetics of solid hydrogen mobility with little theoretical understanding, as the transport is not simple diffusion of a 2-D gas. Further work on these and other systems could be performed with a cryostat that has optical access. A simple experiment would burn a hole in the adsorbed film using a heater or laser. Then using ellipsometry techniques a student would be able to accurately measure the film regrowth as a function of time. Once optical capabilities have been added to the cryostat, other experiments on the adsorption and phase transitions of various two-dimensional films would be possible.

My interests in phase transitions and soft condensed matter have also grown beyond low temperature physics. Currently I am working with six freshmen to study two-dimensional fluid dynamics in soap films. Using a soap film suspended between two nylon wires, we are able to study the turbulence as the fluid flows past various objects. This system is incredibly easy to assemble, and yet it provides one of the best apparatuses for testing fluid dynamics in twodimensions. Our focus has been to study the transition from laminar to turbulent flow, identifying the relevant parameters. For a student who enjoys computer modeling this would be a nice project as they could perform calculations that can be easily compared with laminar flow experiments.

Another system that is deceptively simple to assemble is granular materials. The basic setup for the study of avalanches, pattern formation and convection only requires a few trips to the hardware and grocery stores, yet there is much to be learned from granular materials. While the materials are simple macroscopic particles, which only interact with repulsive forces, the physics is still a mystery. A sandpile at rest behaves like a solid, yet if the slope is increased so that it is greater than the angle of repose the grains will begin to flow. However this movement is not completely fluid-like, as the Navier-Stokes equations do not hold. The discrete nature of the particles may imply a gas-like state but the thermal energy of the system is negligible when compared to the gravitational energy. After all of the contradictions, one is left to conclude that new laws need to be found that can predict the behavior of granular materials. The study of granular materials, much like that of soap films, can be appealing to students as it is easy to observe the phenomena, making it easier for the students, particularly underclassmen, to get excited about the research.

Working on phase transitions and critical phenomena, especially at low temperatures, is something that I find very stimulating and I think students would agree. Experiments such as soap films, granular materials, binary fluids and liquid crystals can offer students the opportunity to study more novel systems. With the equipment from the wetting experiments it would even be possible to look at friction and adhesion in various systems, including biological ones. Studies of quantum chaos would also be possible with a modest amount of additional equipment. As you can see, the equipment can be used to investigate many different phenomena, offering the students different projects to help match the students with the project that is best for them. When the experiments are combined with a strong mentor- student relationship, the students are able to practice valuable skills and begin the lifelong journey of exploring the world around them, which is the essence of the liberal arts education.