January 7, 1999

Last week I had read some papers on granular material physics, and was given eight problems to do. I had requested these problems so that I would gain a better understanding of Mohr's circle and how it could be used to find coordinates on an object where the shear stress was zero. Today, we went over the problems, and I put up my method of solving them on the chalkboard in one of the physics classrooms. Dan and I solved the problems together because there were still a few questions I had about what the different features of Mohr's circle represented. When we got to the last problem, we discovered that it involved the use of a very important equation, and it would greatly benefit me to know how the equation was derived. So, we went over that derivation, and went on to apply techniques of geometry to solving a related problem to compare our geometrical answer and that found through our derived equation.

The rest of the day was spent doing hands-on work. In another room of the lab, Dan had an experiment set up. It consisted of between 1830 and 1930 pentagon-shaped photoelastic beads caught between a flat circular container and an inner circular rotating core. The core had plastic gear teeth on it so that the beads would get caught as they passed by. As the core rotated, the temporarily-caught beads would push against others in the periphery, setting up stress chains that were visible through a polarizing filter. His experiment involved increasing the number of beads, which he called the packing fraction, in the turntable and seeing how the number of stress chains appearing is affected.

I had become familiar with the experiment through reading material that had been posted out in the hallway, but I have never actually done anything with the experiment until today. I was given the task of building a new frame for this "turntable" experiment, as I like to call it for lack of a better name; Dan wanted to fit the core with a torque sensor that would raise the height of the core several centimeters, and the frame had to be raised correspondingly to keep both the core and the container at the same level. I did some measurements, cut a few pieces of aluminum Dexion strips, connected them together with screws, and made a frame that was sturdy and adequate for the job. However, making it out of steel Dexion would make the frame even less sensitive to vibration, and Dan adopted my frame design to make a steel frame after I left.

January 14, 1999

Today, Dan wasn't on campus because he had something important to do. I got to work with Ben Painter, another grad student working for Dr. Behringer and doing similar research. His experiment involved placing 800 small steel beads on a flat, slightly tilted, smooth closed surface, and shaking the surface with a shaking mechanism at different low frequencies to see how the particles move. He took two-minute videos of all his trials, and he had written a computer program over two years that would allow the position of every particle in each frame of the video to be automatically tracked, so that the average velocities of each particle could be computed for the two-minute period. His program picked out all the bright spots (reflected light from each particle) against the dark background of the container, and did this for every frame of the video. He had connected the frame advance button of the VCR remote control to a computer, where the computer sent periodic signals to the remote to advance the frame when it had finished determining particle positions for the previous frame. I thought this was amazing; I had always wanted to learn how to make a computer interface with other electronic devices. After all, a computer is also electronic, and I think it would be great if the computer could serve as a control for other electronic devices instead of just being used to play games, write essays, and send e-mail.

We both counted eight hundred beads for use in the next experiment. After he gave me a tour of his lab room and explained his experiment, he put eight hundred beads into the plastic container and started the experiment, videotaping two minutes of it. We were discussing the patterns of motion that we saw in the container; it seemed that at this particular frequency, the particles resembled a sand pile, where particles slowly descended on one side like sand falling off the side of a sand pile. Frequently, the particles would form hexagonal networks, which were likely configurations of greatest stability, but no one knew why they formed these patterns for sure. After that was done, I watched him analyze the data, and I asked lots of questions about how he was able to design and write his program. It didn't take him all of two years; he had spread the work out over two years, never intending to take all the small programs he had written to make this larger program until a few months ago. It was an incredible program. I definitely want to be able to use computer programming in this way next year.

January 21, 1999

Last week I was given a paper that discussed an early attempt to explain granular material motion. Although the reasoning behind this attempt proved to be fundamentally incorrect, the thought process the researcher used was still good to learn. At the latter half of the paper, where current theories were contrasted with this older, obsolete theory, we came upon a first-order differential equation. I had already done such differentials in Calculus class, but never of the form presented here. Heavy use of sines, cosines, and variables substituted in from other equations were made, so we decided to go over this differential equation together. I had never seen a first-order differential equation of such complexity.

After going over this equation, I helped to finish building a torque sensor that would sense the effects of stress between the moving beads in the turntable experiment. It operated the same way as the pressure sensor did; the torque sensor contained two plates that served as a capacitor. These were connected to two larger, circular plates, one of which was connected to a rod that was in turn connected to the center of the rotating core. If the core rotated without hindrance at a constant angular velocity, the torque sensor would give a constant capacitance reading. However, if particles obstructed the core's motion, then the capacitance across the capacitor would change. Through this sensor, the capacitance was directly proportional to the amount of stress present between the particles.

We had to move the capacitance bridge, which was the device used to display capacitance readings, to the other room where our experiment was. As we disconnected everything we needed from one room and reconnected it in the next, we discovered that the torque sensor was not working. Before, we had a few problems with slight motion of wires causing fluctuations in capacitance readings, but now, the sensor wouldn't work at all. We went through the circuit with a multimeter to try to find any disconnections, and in about fifteen minutes, we found one and fixed the problem.

Finally, we had to make changes to the turntable experiment so that it would hold the torque sensor. We dismantled the turntable so we could put the torque sensor at the very bottom of everything, positioning it so that the rod from the core could be easily pushed into the top part of the torque sensor. The torque sensor had two long, yellow wires trailing from it so that as it rotated, capacitance readings could still be taken as excess wire just became wrapped around the torque sensor. We had to find someplace to put about fifteen feet of excess wire so that its weight would not pull on the torque sensor. I found a really nice piece of Plexiglas with a convenient hole in the center, and because it looked so nice, we dismantled the experiment again so that we could put the Plexiglas just below the torque sensor, where the excess wire would have a place to rest without pulling on anything. We then put the experiment back together and tested it for the first time.

January 28, 1999

I helped to set up two new turntable experiments today. We wanted to test the torque sensor, and so I was first given the task of turning about 1500 pentagonal photoelastic beads so that the side with a highly camera-visible black strip faced upwards. This would allow the position of each particle to be tracked on video. Dan helped out with turning the particles over, and slowly, we reached a packing fraction of 1830 beads on the turntable. Then, we did some test runs to make sure the sensor equipment was functioning correctly. At first, the capacitance readings seemed tiny, so he increased the sensitivity of the sensor. The readings then wildly fluctuated, but he soon found a good sensitivity value for which he got good readings. After doing two test runs, we then went on to the 2-D funnel experiment. For a long time it had occupied space in the turntable lab because there wasn't any other room to house the experiment and because everyone had been busy with other experiments. I suggested that it could be moved to Ben's lab since there was a large area there to operate the 2-D funnel and to set up the camera, which needed to be 68 inches away.

One person each, with papertowels to avoid splinters from its massive frame, grabbed hold of one end of the 2-D funnel's frame and carried it into the next room. I never thought that funnel could be so heavy, being one of the persons moving it; it must have been the Plexiglas panels that comprised the funnel, or probably the heavy timber that was used to construct the frame. However, the next room was only directly across the hallway, so there wasn't much of a distance to travel. We set it down on the floor, and then we returned to get the camera. Mounted near the ceiling was a small CCD camera, and the ceiling was very high; one had to stand on the table housing the turntable experiment just to reach the camera. Before he removed it, he wanted to measure the distance from the lens to the turntable so that he could just position the camera the same distance from the 2-D funnel without having to worry about refocusing; I got him a tape measure and we measured the 68-inch distance between the lens and the turntable. He disconnected the camera from its holder on the ceiling, and I carried it into the next room, where I found a tripod and mounted it 68 inches away from the 2-D funnel.

Here is one of the interesting things about the Physics building that I've managed to discover while doing ordinary work. I had measured out 68 inches, and was going to position the tripod so that the lens would be 68 inches from the turntable, when I ran into a wooden box about three feet by two feet on the floor. It was directly beneath what was once a large device for doing low-temperature physics research, but this apparatus did not present a problem to the tripod. The tripod was short so that the camera could view the portion of the funnel where the pile would form, and it couldn't be extended in any way over the wooden box while still keeping the same line of sight. Therefore, we had to remove the box.

I picked up the box and saw a hole in the floor, through which I could see clear down into the next level of the building. I was amazed. Later, I found out from Dan that people liked making holes in floors when they were doing low-temperature research to house the large, very tall cooling cylinders needed to achieve low temperatures. I had never seen a hole in the floor before; it's just one of those quirks of nature you happen to see when going to physics labs. We found a flatter piece of wood to put over the hole so that the camera wouldn't fall down to the next story; the tripod could be well-positioned above this piece of wood, and finally, our setup was complete. We reconnected some video equipment we brought in from another room, and we were now ready to begin experiments. We did a test run to see how the pile would appear on video, and we experimented with different lighting conditions and degrees of zoom. We got some quite interesting video clips of stress chains forming in the photoelastic beads as they fell into a pile.

February 4, 1999

Unfortunate news for the torque sensor--it wasn't working properly. Dan was getting excessive noise from the sensor as the packing fraction, or density of particles, in the turntable experiment increased. As more torque was being applied to the sensor, it was giving erratic readings, and in about a day or so, he had determined the problem.

In another room of the lab there was a machine where an object could be clamped and spun around its long axis. He had disconnected the rod and torque sensor from the experiment and now, he clamped the rod into the machine and slid on the torque sensor. The machine caused the torque sensor to rotate, so that it appeared like a cylinder. There was another device that measured very small distances; it consisted of a magnetic bottom to lock it in place on the metal machine, and a needle with a blunt end that was connected to something like a pressure gauge. The smaller the distance between the needle and the object, the higher the gauge reading would rise. In this way, he determined that the two plates of the torque sensor were lopsided; the plates were not concentric. The shop had put the two plates together in such a way that one plate was slightly shifted off center from the other, and this was the cause of the excessive noise in the capacitance readings.

Much of the day was spent trying to offset this error by unscrewing the plates of the torque sensor and trying to fit them so that the plates would be as concentric as possible. The screwholes had been drilled improperly, so we had to go down to the shop and enlarge the old holes. Using the distance gauge, we found which side of one plate was more heavily shifted, and we slid the plate backwards to try to get rid of this shift. It was a trial and error task; finally, we got the two plates to be concentric within a few tenths of a millimeter. This was enough for our purposes, and so we carefully rescrewed the torque sensor back together. Just rescrewing meant that the plates could be offset again, so we did another measurement with the distance gauge and determined that the error had only increased by a tenth of a millimeter. That was still good, compared to our previous error of about two millimeters.

We took a break from 2:15 to 3:15 by going upstairs to the second floor to sit in on one of Dr. Socolar's classes. It was a nice class; there were only nine other people in the whole room, including Dan, him, and me. Most of us sat around a nice table with plush seats and lots of elbow room. He gave us handouts related to today's presentation, which was all based on the fact that when particles are allowed to drop randomly, one by one, into a container of a certain depth and width, the surface of the pile will become bumpier as height above the bottom increases. There were many things that had to be accounted for when trying to find a model for this observation, and we went into a mathematical discussion about delta functions, nonlinear terms, and the relationship between certain variables.

February 11, 1999

I attended the second of Dr. Socolar's three talks, and learned more about how particles that fall on top of one another in a flat container can be modeled with differential equations. This talk was basically a continuation of the first, except that he went into a more thorough discussion of the mathematics behind the theory. Dan explained many of the terms Dr. Socolar used, promptly after the talk ended. Also, we did ten runs of the e2-D funnel experiment, observing that during each run, more and more of the cylindrical photoelastic beads were beginning to turn over on their side and become stuck between the Plexiglas panels. Normally, they would fall with their bases parallel with both panels, but because the large sheets of Plexiglas had remained in a vertical orientation for a long time, they had started to buckle slightly, although spacers were placed between the panels beforehand to minimize this. When the particles fell into one of the areas where there was more space between the panels, they turned over, and when they reentered an area of normal spacing, they became stuck. With every run that we did, at least one more particle would turn over, and by the fifth run, there were enough bad particles at one side of the pile that the shape of the pile had become distorted due to good particles having to move around the stuck bad particles. The pile was beginning to grow dramatically lopsided, and we determined that it was time to do something about the twenty or thirty bad particles that we had in probably the fifteen hundred that were inside the funnel.

We tried to get all the good particles into the upper funnel, leaving the bad ones in the lower funnel where the pile would form, and where we could easily remove them. We spent about thirty minutes of great time trying to keep all the bad particles from falling down into the good side of the funnel, and I thought this was hilarious. We were both bending over this huge contraption, and the only thing we really thought about was the location of all the bad particles. We absolutely could not allow one bad particle to enter the other funnel, and several times one actually approached the neck of the hourglass as Dan tried to get all the good particles to go through. He wanted to get a few more good particles through, but a bad one would hang precariously close to the neck, and any slight movement would likely send it falling through. I just knew it was going to fall through, but none of the bad ones ever did; we were careful.

February 18, 1999

Today, Dr. Socolar gave his last talk on quasicrystals and Penrose tilings. The grad students and I had a long talk on Hamiltonian functions, which I discovered I will learn more about in my junior year of college, and I watched Dan analyze some data from the turntable experiment. He had a problem with the rod rotating inside the torque sensor; the ball bearings that he had placed there to allow the rod to rotate was not doing their job. He then asked me how I thought he could solve this problem, and I said that he could probably do a Fourier transform to get rid of the sinusoidal signal that he got from the lopsided rotation of the rod within the torque sensor. He said that he thought about that way, but Dr. Behringer then told him of an easier way.

He made an RC circuit that served as a high-pass filter. It would allow him to filter out the sinusoidal component of the graph of capacitance reading over time, leaving only the random noise which were the true capacitance readings. This was an ingenious idea. It turned out that he had already solved his problem before I arrived, but he just wanted to introduce me to this new part of the experimental apparatus and teach me a bit more about electronics.