SOAR Proposal for Summer Research 2015

Project: Computer interfacing of an experiment in granular materials

Faculty Mentor: Dr. Kelly Krieble, Associate Professor of Physics, Dept. of Physics and Earth Science

Students: Ljube Boskic, class of 2017 and Rebecca Hamel, class of 2016

Start date: May 26, 2015

Duration: 10 weeks.

Project Description

Background:

Granular materials – materials that behave as a fluid or a solid depending on the conditions – represent a class of materials that have undergone recent study. Such materials can often be used to model complex phenomena such as avalanches, earthquakes, and food storage and transportation problems. As such they represent an exciting area of study, especially at the undergraduate level where students are not normally exposed to such topics in the standard curriculum. The particulars of this research involve studying the dynamics of a system composed of a "sandpile" of small plastic spherical beads as it is built up and experiences avalanches, which are then measured in terms of their size and frequency as a function of bead mass. The events illustrate a "1/f"-like behavior (where f is the frequency of events of a particular magnitude) in that larger events are less frequent. We hope to gain insight into how inertia and inter-particle forces play a role in the dynamics of these materials.

Proposed Studies:

The overall goal of this SOAR project will be to improve the data collection and control methods that were developed by Ryan Cress for his Honors project in 2008. One area of improvement will involve the counting mechanism employed to determine the avalanche size – previous methods were found to miscount at large sizes of avalanches. For this project, the students will develop a reliable counting process by incorporating improved optics as well as a computer control mechanism involving the use of an Arduino micro-controller – the kind that is currently being used in our sophomore electronics course. A second area of improvement will focus on the bead dropping mechanism control to more fully automate that process and integrate it with the collection program so that both subroutines interact with one another. Each student will address one of these improvements, with collaborative work done on blending the control and collection mechanisms together. The students will have the opportunity to collaborate together in the writing of the control code, yet still work on their own aspect of the experiment – each aspect of the project should encompass more than enough work for each student, yet the students will learn from each other's programming skills. Data collection will be on the same apparatus, but each student should be able to collect their own subset of individualized data to examine distinct points of study

– inertial effects due to mass differences in the beads for one student, and an overall study of the avalanche frequency and size distributions for the second student. The proposed work will involve apparatus design and engineering, electrical interfacing, programming in C++, computer control and monitoring of the particle drop rate and flow control, optics for data collection as well as associated electronics, and timing control. Collected data will be compared to historical data for this experiment, with testing employed using controlled avalanches.

Faculty roles and responsibilities: The faculty member will assist the student in performing a background literature search and understanding the physics underlying granular flows, will provide expertise in the experimental techniques and approaches and the design of the experiment, instruct the student in the use, calibration, and handling of the apparatus to be used during the project, assist in the implementation of the project goals, and prepare the student for presenting the results of the project in multiple forums and formats – students will be expected to present their work at the sectional American Association of Physics Teachers (AAPT) spring meeting in 2016.

Student roles and responsibilities: The student will actively participate in the study of the background material and investigations of prior efforts in experimental development, will keep experimental logs of their work, will collect data in a thoughtful manner by examining sources of error and limitations on the equipment, will apply creative ideas to solving challenging problems, and will prepare a final report in multiple formats (poster, paper, presentation) and for multiple audiences, presenting their findings at our local physics teacher conference as well as during Scholars Day in spring 2016.

Timeline of Milestones

Weeks 1-2: gathering and fabrication of necessary equipment and instruction on proper operation of the current experimental apparatus, performing a literature search and constructing an annotated bibliography of references, and studying the background theory of granular materials, operation of the base experimental apparatus to become familiar with the components

Weeks 3-6: preliminary work on interfacing, and modifications of select parts of the apparatus (optics and mechanicals)

Weeks 7-10: final programming, data collection, and presentation of results and process – data runs for this experiment tend to span multiple days, so a good amount of time needs to be dedicated for this portion of the project. Once the proper computer control and acquisition is achieved, the process is very much automated.

Student engagement in discipline specific scholarly research

Research on granular materials is very much a new area of research within our curriculum. Our approach (using a larger than normal system for ease of study) is one which is somewhat novel within the granular material community, but has many advantages. As such, the results achieved with this project should be quite suitable for submission to an appropriate journal, with students involved in the paper writing and submission process.

Description of contributions, benefits, and opportunities for students

The students will develop skills that are valued in the successful physicist: the ability to solve technical problems, the ability to successfully interface computers and controllers to various pieces of scientific equipment for common types of data collection, data analysis techniques such as descriptive statistics, curve fitting, and error analysis. The students will also develop communication skills such as technical writing, presentation skills, and computer programming – skills which transcend many disciplines. The students will also learn to manage a project as well as developing personal time management skills, and keeping an experimental journal. By presenting at our local physics teachers meeting the students will network and interact with other physics and engineering students as well as other faculty within the discipline. Both students are also fully experienced in the use of the Arduino, having learned to use it in PHYS221, Linear Electronics in Fall of 2014. They get along well with people, have collaborated together in their electronics class, and have a genuine interest and excitement for this project, so I expect that they will work well together and produce a product that is greater than the sum of its individual parts.

Preliminary Literature

Ryan Cress, “The Effect of Particle Mass on the Dynamics of Avalanches on Three-Dimensional Granular Piles”, 2008 Honors thesis.

David W. Grumbine, "Structural Basis of Avalanches on Two-Dimensional Granular Piles", Ph.D. Dissertation, Department of Physics, Lehigh University (1998).

Thomas K. Nishino, “1/f Dynamics of Avalanches on Three-Dimensional Granular Piles”, Ph.D. Dissertation, Department of Physics, Lehigh University (1999).

Galeriu, C., Edwards, S., and Esper, G. “An Arduino investigation of simple harmonic motion”, The Physics Teacher, vol. 52, March 2014, pp. 157-159.