Simulation & Experiment of Normal Force in Micro-Gravity Environment

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Introduction

- In a microgravity environment, even relatively simple systems exhibit behaviors, which don't generally occur when gravity is a dominant force, and their occurrence is often contrary to common intuition. Videos from the Portland State University Dryden Drop Tower illustrate and document a wide variety of such phenomena. My project is inspired by a video shown in PH 211 of the behavior of a stack of coins initially at rest in the drop tower capsule and what happens when it drops, and the coins become effectively weightless.

- From our initial investigation, my faculty mentor and I expect there are several key factors at play, including the initial normal forces that cancel out the initial weight, the elastic properties of the coins and the base plate the coins initially rest on, effects from the release mechanism of the drop tower, and the size and density of the coins that can introduce scaling effects.

- Such situations involving normal forces in micro-gravity seem to be an entry into important mathematical model building for explicit understanding of these kinds of fascinating events. In addition, these simulations can suggest, and be tested on, other drop tower experiments. And simulation program predictions could be compared with other archived drop tower stacked coin videos.

Goals

- Develop simulations that provide explicit explanations and explore the motion of a variety of stacked coin situations of the sort tested in the drop tower.
- Contribute to clarity of explanation in general and to understanding of the role of the variety of factors involved in initiated and steady state microgravity environments.
- Given that this behavior has pedagogical value, increase this value to education through more explicit modeling, testing and clarity of understanding.

Experimental Design

- Create a simulation to show the behavior of a multiple stacked cylindrical objects (“coins”) after the onset of microgravity and compressed stacked objects released in microgravity.
- Using a video of stacked coins tested at the Dryden Drop Tower.
- Our simulation developed, which accounts for a variety of characteristics of the materials including density, elasticity, size, and isolate release mechanism effects.

Stack of Coins Experiment

Video Analysis

- Using this video footage as a starting point I began analyzing the motion of the coins in the stack with Logger Pro 3. Which created a motion diagram for the coins that were analyzed. In the data collected I noticed that each coin had the same linear pattern but around the 0.1 seconds mark in the drop a disturbance occurs in all the coins. The disturbance that was common in each coin analyzed appeared to create a waveform oscillating until the drop is complete.

Video Analysis Data

An explanation for the disturbance that my mentor and I determined to be the cause was at the initial drop a small vibration occurs on the platform holding the coins and the camera filming.

This vibration then transfers to the camera which distorts the coins motion diagrams while they are falling to appear to have a waveform.

We determined that this was a useful insight because now we know there may be more than Normal force interactions affecting the behavior of the stacked coins.

Due to the nature of the waveform in the motion diagram we identified the other possible interactions to be a spring force that originates in the platform then transfers to each individual coin in the stack.

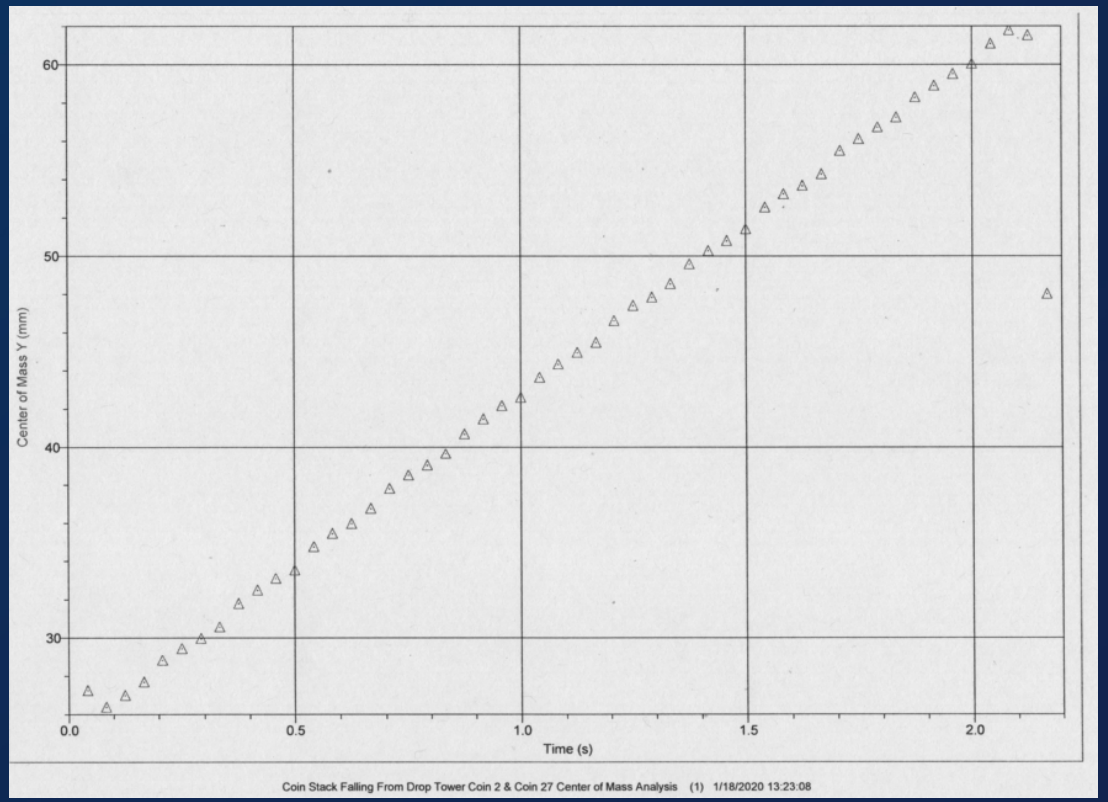

Figure 1. Motion diagram of the Center of Mass for a stack of 27 coins in Dryden Drop Tower

Simulation Construction

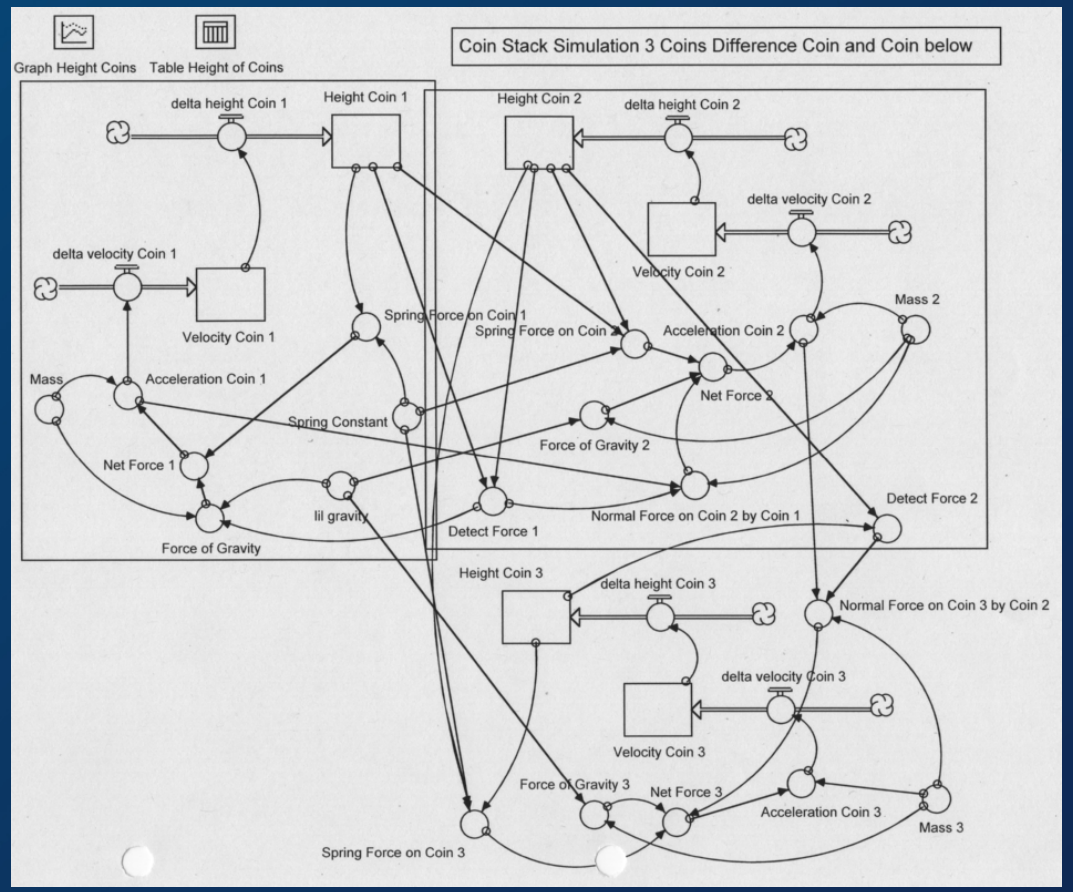

Figure 2. Coin Stack Simulation of 3 Coins in STELLA

Using the data and knowledge I gained from analyzing the video footage, the next step in my research was to create a simulation for the stack of coins with the systems dynamics software STELLA. Initial simulations were conducted on only a single coin to simplify the logic necessary for a complete simulation. Once this was accomplished another coin would be added to the simulation. I followed these steps until I reached 10 coins in the stack for the simulation.

Simulation Results

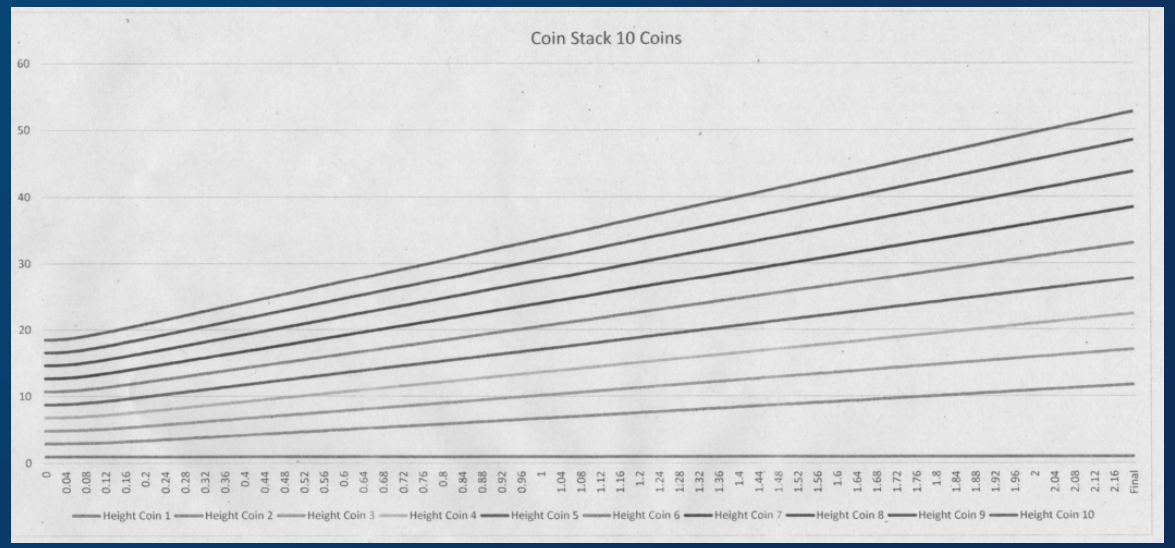

Figure 3. Simulation Results for a Stack of 10 Coins

My results from the simulations conducted with a stack of 10 coins shared this pattern like the video. The top 2 coins would stay in contact as they rose to their maximum height, with the coins further down spreading apart from each other more the further to the bottom of the stack the coin began. This appears to derive from a vibration that occurs when the drop capsule begins its descent. The explanation that I found to justify this behavior is associated with the change in momentum which functions like a spring in a collision at the moment low gravity acts on the coins.

In addition, with the coins higher in the stack a greater acceleration is measured when the simulation is conducted compared with the coins lower in the stack.
Based on the model created by the simulation it shows that effects of normal force are moving the coins further apart as weightless occurs.

SCORE Experience

The experience that I personally gained from the research to simulate the behavior of a stack of coins in microgravity was insightful in showing me the work necessary to find an understanding of something that was not designed to have a correct answer, the way a classroom setting would have. As a computer science major I enjoy being able to read documentation for a computer language to accomplish a task, which was necessary for a portion of my research using STELLA. Along with learning about new software, such as Logger Pro to analyze motion of objects from a video. Through this experience I began to feel comfortable with asking questions that I needed help with to ensure that I was representing the behaviors of the coins properly. I learned that a broader view of the physical situation is necessary to understand the behavior being researched, as this may have an affect on the dynamics that I am focused on.

SCORE Experience

My perspective on research in general was supported from this experience as a positive opportunity which I would be interested in further exploring as a career. This has taught me the seriousness when explaining why I am doing something a certain way that it must have a substantial evidence behind it for it to be considered useful and correct. Which I really enjoy because I only want to use or have someone use something that has concrete evidence to justify the accuracy of the results it wants to represent.

Citations

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