SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Rockets vs. Kinematics
Name of School	Ithaca College
SPS Chapter Number	3183
Total Amount Requested	$2000.00

Abstract

We propose to examine the difference between simple and complex rocket trajectory models (with experimental comparisons). We are using model rockets because they can be considered a relatively simple system some students have experience with. A motivation for this project is furthering our knowledge of how physics relates to reality.

Proposal Statement

Overview of Proposed Project

A common thread in all physics classes is calculating results that can be applicable to real-world problems. A common question that comes up in these classes often is: How do the results we calculate using simplified assumptions, like zero air resistance, compare to the actual results of the problem? To investigate this, we will use model rockets, a relatively simple system. Model rockets can be considered simple because they consist of an acceleration upwards, and then projectile motion from there. Because of this, we plan to calculate the trajectory using common assumptions, such as neglecting air resistance and a parachute, as well as calculating the trajectory without common assumptions. We predict that the difference between these calculated results and the actual results will be measurable. We also plan to answer the question: How can we measure data about the rocket (such as trajectory and altitude) without affecting the path of the rocket? We're doing this project for three main reasons. 1) It will enable us to understand when more advanced physics is necessary to properly model the real world. 2) It allows us to advance our building capabilities, getting us to the point where we build our own rockets. 3) Shooting off rockets is no small event, and when students outside of our SPS Chapter see these rocket launches, they will be inclined to engage with our SPS chapter! The project will begin with us purchasing the rockets we intend to use. Model development of both simple and complex trajectories will begin simultaneously. First, determining trajectory ignoring factors like air resistance, and later acknowledging them. Following that, we will modify the rockets so that we can receive their actual telemetry data. Finally, the physical and modelled data will be compared.

Background for Proposed Project

Projectile motion is one of the first concepts all physics students learn. This is because it builds physics skills that are commonly used, by connecting motion in both the x and y plane, using base kinematics concepts. Because students can break the projectile motion into their x and y components, this allows them to predict the trajectory of objects. A real world example of projectile motion is the model rocket. In Ithaca College's first physics class, model rockets are one of the key examples that is used to discuss projectile motion. This is because model rockets can be broken into different stages, where the motion of the rocket can be predicted. However, the instructor invites students to make simplifying assumptions such as neglecting air resistance and the effect of a parachute. In upper-level classes, the simplifications are discarded, but the calculated results are very rarely compared to the real-world result. This is because it would be extremely difficult to compare a calculation from an advanced physics class to practice. Our project seeks to explore this. We would attempt to modify model rockets in order to be able to track their trajectory to a small degree of uncertainty, by tracking their telemetry, and compare that to the simplified and complex calculated results.

Expected Results

We can expect there will be measurable differences between our calculated trajectory and the actual trajectory of the rocket. However, this difference is expected, and opens up our next step of changing equations to be able to model the calculated trajectories similar to that of the real world. This is where the true computational and modelling research begins as we venture further into the edges and poorly defined complexities of atmospheric trajectories!

Description of Proposed Research - Methods, Design, and Procedures

- We're calculating the trajectory of a model rocket as if the problem was a problem in one of our introductory physics classes.
  - We shall ignore air resistance, the spin of the rocket as it's falling,the effect of the parachute, treat the acceleration of the rocket as a constant when it's going upwards, and ignore wind.
- After the results from our first trajectory are found, we will increase the fidelity of our model.
  - The main difference between the two calculations will be that we will factor in all the things we ignored in the first trajectory.
- Then the two models will be compared.
- To find the actual data, we'll modify model rockets and track their data
  - We will use a gyroscope, an x-y-z accelerometer, and an altimeter to do this
    - We will also attempt to add a GPS module and a bluetooth module, in order to retrieve the data much more easily
  - We'll 3D print holders that will be glued inside the rocket, so the components of the circuit can easily and securely fit inside the rocket
- Once we launch the rockets and get a result, we'll compare it to the two calculated results, which will give us the actual difference between calculating kinematics and real life

Plan for Carrying Out Proposed Project

Multiple members of SPS will assist in this project, but two freshmen who have completed their introductory physics course will be leading the research. Since they have only completed their introductory physics course, if they have any questions about actually executing the project, they will consult a faculty member that is already on board for the project. For the kinematics equations without assumptions, they will consult upperclassmen who are involved in SPS, as they have taken upper-level physics classes that teach mechanics without assumptions. For the engineering part of the project, multiple students in SPS have expressed an interest in engineering, and would be willing to help out with figuring out how to 3D print proper holders. Ithaca College has multiple lab spaces in the building the physics department is housed in that would be of use for building rockets, and there is a 3D printing lab that would be used for the 3D printing aspect. Ithaca College is also has many open fields, and these would be used for the actual testing of the rockets.

Project Timeline

1. Begin model development and estimating trajectories.
2. Finish calculating the trajectory of the rocket with basic assumptions, that were mentioned in the description.
3. Obtain the rockets that we will launch and use to test the accuracy of our estimations.
4. Begin modeling a prototype using 3D printed holders for the purchased materials.
5. Complete a working prototype in order to use our telemetry data. - **Finish by April 30, 2020**
6. Complete the interim report - **Finish by May 31, 2020**
7. Work in more complex kinematics and higher-level physics in order to generate a more accurate trajectory estimate.
8. Finish a working rocket, with the modifications to record telemetry data, as well as send us the data. **Finish by November 30, 2020**
9. Compare our calculated data with our actual results, and complete the final report. **Finish by December 31, 2020**
10. Continue modifying our models and rockets

Budget Justification

- HiLetgo BMP180 Atmospheric Pressure Sensor, HiLetgo GY-521 3 Axis Accelerometer, Arducam PRO Mini Development Board, GPS Module NEO-6M
  - These are all the parts we will need for the arduinos we are using. This will allow us to to track altitude, acceleration, and the rockets GPS location. The reason why we are only getting 15 of the Development boards is because they are sturdy, and we will be able to reuse them in multiple rockets.
- 3D Printer Filament
  - The 3D Printer Filament will be used for creating the holders will house the arduinos in the rockets. We are asking for two of them because we expect that there will be many different prototypes and shapes needed to build our model.
- Estes Magician, 3/16” Two-Piece Maxi Launch Rod, Prota-pad E Launch Pad, 2 D12-5 Engines
  - The Estes Magician will be the main rocket we use, and as such we are requesting 12 of them. Since Ithaca College is located on the side of a mountain and right in front of a forest, we need to account for rockets getting stuck in trees, drifting away, or just breaking. The 3/16” Two-Piece Maxi Launch Rod and Prota-pad E Launch Pad are the launch mechanisms for the rocket. We are requesting two of them, because there is a possibility that one could break. The D12-5 Engines are the engines we are using for the Magician rockets, and they come in sets of 2. We are requesting 13 sets of 2, or 26 individual engines, because model rocket engines have a small chance of malfunctioning. Also, we would like to shoot of the rockets multiple times, and having excess will allow this.
- Estes Space Crater, 3 C6-3 Engines
  - The Estes Space Crater is a simpler rocket, and will be very helpful with getting students started in building model rockets. We intend to use these as our first prototypes, and have them be the first

rockets students build. Since they will be the first rockets students build, we are requesting 8, as it will take multiple tries to successfully build a rocket. The C6-3 Engines are the engines used to launch the Space Crater, and since they come in sets of 3, we are requesting 15 of these sets. This means we'll have 45 engines for the Space crater in total, and will allow us to shoot them off multiple times.

- Estes Multi-Roc, C6-0 and C6-5 Engines
    - The Multi-Roc is the most advanced rocket we're buying, and it is also the most customizable. The Multi-Roc is also a multi-stage rocket (hence the name), and as such would give us a different trajectory than all the other rockets. This will be helpful towards the end of our research, as it will allow us to apply our calculated model to other situations. Since the Multi-Roc is multi-stage, it requires two different engines, and these would be the C6-0 and C6-5 Engines.
- Porta-pad II Launch Pad
    - Conveniently, the Multi-Roc and Space Crater use the same launch pad, which is the Porta-pad II. We are requesting two of these, so that in the case of one breaking, we have a back-up.
- Batteries/Sensors/Electronic Components
    - The final part of our budget is dedicated to any miscellaneous electronics we need. We will be experimenting with different battery sizes, as well as different connectors from the battery to the arduino. Sensors are included in this section as well, because if the sensors we are already purchasing break, and we need new ones, we will be able to purchase them. Additionally, we will likely come across the need to purchase sensors or electronic components that we cannot currently predict needing.

Bibliography

- Prices for arduinos and their components found on Amazon
- Rockets, Launch Pads, and Engines prices found from Estes Rockets
- Basic Kinematics principles from *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics (4th Edition)* by Randall Knight
- Rocket Engine facts found from https://www.grc.nasa.gov/WWW/k-12/rocket/rktengine.html