SOCIETY OF PHYSICS STUDENTS

An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	**Swinging Into Science**
Name of School	**Lawrence Technological University**
SPS Chapter Number	**3673**
Total Amount Requested	**$2,000.00.**

Abstract

Lawrence Technological University proposes an interactive outreach program for students to derive and test a mathematical model of a physical pendulum. This program will have students create a pendulum and computationally solve the differential equations of motion involved. The motivation for this project is to have students of all majors in the chapter be more involved in gaining student skill development, as well as giving all students an opportunity to learn more about physics.

Proposal Statement

Overview of Proposed Project

Research question and brief description: Lawrence Technological University's (LTU) Society of Physics Students (SPS) chapter is seeking to develop an intermediate classical mechanics laboratory experiment that will be used as an interactive outreach demonstration tool. The laboratory exercise will focus on the concept of the Center of Oscillation of a physical pendulum. The learning outcomes of the laboratory exercise include theoretical work, experimental design and sensor integration, computational methods for equation solving and data analysis, and data visualization and communication. The goal of the outreach demonstration is to allow the audience to adjust the pendulum to find multiple different configurations of the pendulum starting angle and center-of-mass-to-pivot distance that have the same oscillation period. The pendulum will have an attached display that will show the computational solution, developed in the lab, that fits the oscillation data to find the period and damping coefficient. Information about the physics of the system will also be shown on the display.

Motivation: The project will be a fantastic opportunity for the members of LTU SPS to gain experience creating hands-on experimental apparatus and writing a fully-fledged research paper. Another goal of this project will be to engage members of SPS as well as other undergraduates at LTU in what the research process looks like.

Research goals: The physics research goal is to build a device that measures the center of oscillation of a physical pendulum. As a laboratory exercise, the goal is to connect experimental design and computational data analysis. We also plan to publish our exercise in the American Journal of Physics.

SPS connection: This project will include several students who are enthusiastic about physics but come from several different disciplines. Students contributing to this project include Alanna Makarchuk (chapter president), a computer engineering major, Tia Abbas (chapter vice president), an electrical engineering major, Maria Lomas (chapter secretary), a mechanical engineering major, Jason Best (chapter treasurer), a computer engineering major, Gabe Dresen is a mechanical engineering major, and Luke Hudy is a physics major. Our hope is that this interdisciplinary involvement will not just serve the project, but will also stimulate broader participation in the LTU community.

Background for Proposed Project

We will derive the physical pendulum equation following common classical mechanics texts such as Rev. [1]. We also include damping-based angular speed to find.

$$\frac{d^2\theta}{dt^2} - \frac{c}{I}\frac{d\theta}{dt} + \frac{mg\ell}{I}sin(\theta) = \boldsymbol{0}. \quad \textbf{(1)}$$

Here θ is the angle of pendulum arm with the equilibrium (vertical) position, I is the pendulum moment of inertia with center of mass m. The distance of the pivot point to the center of mass is ℓ, and the damping coefficient is c. This equation is not solvable analytically so we will write a Python code using the Runge-Kutta 4th order method to solve it. We will also write a routine to fit our solution to experimental data to extract the damping coefficient and oscillation period. One of our goals is to have this routine run automatically when the pendulum is swinging.

We will build a pendulum that has an adjustable starting angle and center-of-mass-to-pivot-point-distance. Starting conditions and oscillation data gathered from sensors attached to the pendulum will be sent to a microprocessor or computer such as a Raspberry Pi where they will fit and extract the period. This process will be automated, recorded, and displayed for the user.

Expected Results

The center of the oscillation period depends on both the initial angle of the pendulum and the center of mass to pivot distance. We will measure the pendulum period as a function of these two parameters and plot the 3D shape. Contours of this shape will show initial parameter configurations that have the same period. The primary results of the project will be an assembled interactive educational pendulum. It will have a variable center of mass and starting angle. It will have a sensor attached to calculate the position vs time of the pendulum. That data will be analyzed in a program and users will be able to see the results of the analysis on a screen. After extensive testing using an accurate rotary motion sensor, the derived model will give a precise and accurate prediction of the pendulum's position, and show users how it was obtained.

Description of Proposed Research - Methods, Design, and Procedures

Researching and designing the pendulum. The initial stages will include researching and selecting sensors for the pendulum that will provide sufficient information needed. The primary specifications that we will be taking into factor will be the cost, resolution of the angle, the frequency at which it reports data, and how easily we can integrate it with the chosen microcontroller. We will also research and choose a microcontroller or computer such as a Raspberry Pi that will run the code and project information to a screen. This entire project will be designed to be one complete setup that will fit on a movable cart for outreach events.

Building the pendulum. We will be using our fabrication lab on campus to machine some of the parts like the pendulum arm and sliding mass. Once these have been built and the ordered parts have arrived such as the sensors, we will assemble the parts of the pendulum and begin experiments in order to obtain the pendulum's period from the selected angles to be used later.

Write the code that will fit and extract the period of the pendulum. We will write Python code that uses the Runge-Kutta fourth-order method to solve the governing differential equation listed above. We will use that to fit the data from our pendulum with the results from our Python code to extract the damping coefficient. For our outreach aspect, we will create a program that will display important information such as the damping coefficient and the period of the most recent pendulum.

Write the research paper. With the aid of our faculty advisors, we will write and publish a research paper to the American Journal of Physics.

Plan for Carrying Out Proposed Project

Personnel - Members of LTU SPS and other interested students in various STEM majors will contribute to the construction of the testing rig and dissemination of results. All majors will be encouraged to participate in the project, as well as learn how it works.

Expertise - We will have the support of the LTU Arts and Sciences Department, but specifically our SPS faculty advisors will be overseeing and guiding this project. This includes Dr. George Moschelli and Dr. Bhubanjyoti Bhattacharya. Both are Assistant Professors of Physics at LTU and hold a Doctor of Philosophy in Physics.

Research space - The work will be done in LTU's physics labs and project spaces. The end result will reside in our physics lab and will be taken out for demonstrations and contribute to various other Outreach Programs.

Contributions of faculty advisors or the department (equipment, space, etc.) - Our department has provided us with the use of their laboratory equipment, and encouragement to undertake the project. Additionally, we have metal and wood fabrication workshops on campus that we can utilize.

Project Timeline

This section is the timeline for carrying out the project. It includes the key milestones and the dates by which important steps need to be completed to finish the project on time.

Project Timeline	
Submit Proposal	November 15th
Convene for Project Discussion for Purchasing	November 30th
Research, Pick Materials, and Design Pendulum	December 7th
Submit Purchase Orders	January 8th
Begin Building Pendulum and Writing The Code	January 20th
Gather and Analyze Data	February 20th
Begin Writing Research Paper	March 1st
Showcase Pendulum in Outreach Programs	April 11th
Begin Writing Interim Report	May 1st
Submit Interim Report	May 31st
First Meeting of the School Year - Discuss Improvements to Design	September 5th
Finish Research Paper	November 29th
Begin Final Report	December 1st
Submit Final Report	December 31st

Budget Justification

The pendulum itself, and interactive display will be fabricated on-site by students in the chapter. We budget **($800)** for the materials, including metal for the pendulum itself, bearings, screws, and clamps and support structure. The adjustable mass to move the center-of-mass and mechanism for accurately setting the initial angle will also be machined in the school's fabrication lab requiring CNC-milling and welding. The pendulum will also require accurate sensors such as a high-precision rotary motion sensor: (**$200)** for data collection. The interactive aspect of the display will require a rolling cart: **($200)** and a monitor for displaying data: **($200)**. A microprocessor, hard drive, wiring, extension cords, and any additional electronics **($400)** will also be required to run code for processing data on consecutive runs of the display and ensure students can see real-time data rather than previous recordings. For outreach events, the chapter will also provide snacks and drinks **($200)** for students**.**

Bibliography

[1] Grant R. Fowles and George L. Cassiday, Analytical Mechanics (7th Ed.), Cengage Learning (2004)