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

Marsh W. White Award Proposal

Project Proposal Title	Build-your-own Quantum: Improved Lab Kits for Studying Quantum Information on the High School-Level
Name of School	Stony Brook University
SPS Chapter Number	#6786
Total Amount Requested	$583.10

Abstract

Stony Brook University SPS will improve upon last year's Mach-Zehnder interferometer/quantum eraser project by visiting high schools with improved kits and making detailed manuals for teachers to build the kits themselves. High school students performing the experiment will build intuition for quantum measurement via hands-on activities involving classical polarizers.

Proposal Statement

Overview of Proposed Project/Activity/Event

Quantum Information Science is rapidly advancing, bringing transformative developments in quantum computing, simulation, and communication that are reshaping science and engineering. However, the behavior of quantum particles defies intuitive understanding of the natural world, making it difficult to convey quantum science to students. This is compounded by the inaccessibility of hands-on experimental tools capable of demonstrating these principles; usual tools for testing quantum mechanics are prohibitively expensive and complex. As such, the subject can frequently leave students feeling disheartened and confused.

Building upon last year's project, Stony Brook SPS members will improve their lab kits and instructional plans for teaching the principles of Quantum Information to high school and early college students. The main goals of the activity are the same: By inserting linear polarizers along each arm of a preassembled Mach-Zehnder interferometer kit, students can better understand interference and the behavior of quantum particles. We demonstrate that a photon given two available paths will be in a superposition of outcomes which results in an interference pattern. After inserting two crossed polarizers, one on each arm of the interferometer, the interference pattern is destroyed. Along the way, the kits demonstrate a quantum eraser: "which-path" information gained from two polarizers can be deleted via an extra polarizer at the output, restoring the interference pattern. Before handling the kits, students first develop a baseline understanding of classical optics via a series of quick hands-on demonstrations involving polarizers, diffraction gratings, and a Michelsohn interferometer. Kits are then distributed between groups of several students and SPS members will make their way around to assist. This was the format of our visits to Wellington C. Mepham High School, The Bronx High School of Science, and Brooklyn Technical High School, and it was successful.

In addition to visiting these and new schools, SPS will focus on making the kits reproducible on the high school-level with teacher guidance. The project serves to allow students of any high school with access to basic chemistry supplies and a 3D printer to learn basic ideas in quantum mechanics tangibly and affordably. In our visit to Bronx HS of Science, teachers expressed considerable interest in this phase of the project. The process of making the kits could become an in-class project or teacher-supervised extracurricular activity spanning several days, if desired. We envision that interested students will make the kit in a small group under a teacher's supervision, using the sample kit, instructions, and CAD files for the 3D-printed frame which we will provide.

In addition to this construction activity, we have also designed a follow-up activity to be done after the initial visit, which like the construction activity will be more independent. Unlike the construction activity, it will be simple to perform, and will go a little deeper into the theory. We will ensure the follow-up activity will be interesting and doable within a reasonable time, and we will remotely stay in contact with schools performing the extension activity to troubleshoot any issues. We believe there is more to be explored than what we can show in a single visit, so a follow-up activity serves to bring a more complete and memorable experience. The activity which we are developing will use quarter or half-waveplates in addition to linear polarizers to illustrate quantum logic gates and the Bloch sphere, as an extension of what the students will learn about quantum measurement from the visit. A significant portion of this grant will go towards testing and making changes to the kits to accommodate the activity. Even if it is infeasible to create the kits or there is no time for the follow-up activity, teachers will still be provided a kit to play with and demonstrate to their future classes!

Our chapter needs resources to iterate on our existing design and provide new kits for new schools. While much of this project will involve refinements in the educational materials, we seek to test and refine the design for a more insightful student experience. For example, the 3D printed frame needs to be updated to accommodate the "eraser" part of the experiment, and it is desirable to engineer built-in methods for rotating polarizers by an arbitrary angle as well as polarizing the incoming light from the laser diodes. We also believe more open ended experiments could be designed with access to optical elements other than linear polarizers, for example using other elements one could simulate quantum logic gates as a possible follow-up activity.

Our chapter has extensive experience with science communication and a long history of STEM education. During our weekly Physics Cafés, we discuss physics with our members, including many underclassmen and non-physics majors. Members of our general body have worked as TAs and peer tutors. Moreover our former executive board consisted of students in optics research, and our current members are excited to pick up this project, complete their mission, and take it in new directions.

As stated previously, this project builds on the success of previous experience including our *Illuminating Quantum: A Hands-On Lab Kit to Study Quantum Information* (2025, Marsh W. White Outreach Award) and *Making Waves: A Hands-On Interference Lab for High School Students* activity (2024). Our chapter is confident that we have built up the educational and technical expertise to anticipate, understand, and solve the challenges high schoolers will face when learning the subtleties of quantum measurement and experimental design.

How Proposed Activity Promotes Interest in Physics

Quantum Information Science is an incredibly interesting topic that is notoriously inaccessible to students and the general public. Stony Brook SPS members can remedy this issue with our unique design for a low-cost interferometer. Building on previous work, we present the rare opportunity for students to connect abstract physical concepts to something students build with their own hands and take pride in. Along with our accompanying lesson plans to demystify underlying principles, the lab activity will be novel and memorable enough to spark an interest in quantum physics.

Today's rapidly changing technological landscape requires a quantum-ready workforce, yet many high schools lack the resources to introduce these concepts. As a result, students who might thrive in physics may never have the opportunity to explore the subject deeply. The Marsh W. White Award will enable our chapter to bridge this gap by providing both tools and encouragement, allowing students to handle quantum experiments firsthand. With the interferometer, students will not only gain insight into a complex realm of science but also develop essential skills for research and industry, as interferometry is fundamental in both physics and engineering. Quantum physics can be intimidating, but this hands-on approach shows high schoolers that it's accessible, exciting, and within their reach; we aim to show high schoolers: *You can really learn quantum physics*.

Plan for Carrying Out Proposed Project/Activity/Event

Last year, several members of Stony Brook SPS, with assistance from Stony Brook QuEST faculty members (Quantum Education for Students and Teachers program [NSF Award No.: 2148467]), developed low cost Mach-Zehnder Interferometer kits capable of performing a Quantum Eraser experiment. We will build a series of lab kits improving upon that design, and expand upon last year's lesson plan to emphasize the core principles of Quantum Information Theory, including qubits and quantum measurement. We will test and troubleshoot these lab kits and lessons by holding a pilot lab activity for Stony Brook underclassmen in coordination with the Stony Brook undergraduate physics laboratory staff, which will again be the testing ground for our educational materials.

After the success of our Interferometer Lab Kits last year at Wellington C. Mepham High School and our Electromagnetism Lab Kits at Longwood High School in years prior, and also at the schools we visited last year, SPS Stony Brook will continue to expand and build upon this work. Dr. Angela Kelly, associate director for the Institute of STEM Education and principal investigator of QuEST at Stony Brook, has assisted us in contacting the science directors of local Long Island high schools, namely Smithtown and Comack, after the success demonstrated at Mepham. She remains a valuable connection for this project.

The executive board members of Stony Brook SPS who worked on this project last year have since graduated, but the project continues to be run by a group of 3-4 ambitious undergraduates who want to see the project reach its full potential. We remain in close contact with the original members and have their guidance as well.

Project/Activity/Event Timeline

The schools which we have visited are enthusiastic about hosting this activity with us again. Besides these, we plan to contact local Long Island school districts and achieve a wider reach. Our timeline, adjusting for limitations experienced last year, is as follows:

Throughout December and January, we plan to update the lesson plan and instructions based on last year's experiences. Simultaneously, we aim to test modified lab kits from December through mid February. We will host a general body meeting to test the revised lesson plan with Stony Brook undergraduates during the last week of February, and spend early March iterating and improving our lesson structure. Throughout this time, we will coordinate with our direct connections with other high schools to select dates in March, April, and May for outreach events, preferably earlier. During the visit, we will ask teachers/students if they are interested in performing either of the follow-up activities, which includes making the interferometer and performing the follow-up activity. If interested, we will remain in contact with them remotely to assist. At the end, we will survey participants and discuss with educators to evaluate if we met our goal of making optics approachable and exciting.

Activity Evaluation Plan

For each high school where we do our demonstrations, we will record attendance and gauge what students know about optical physics via informal discussion. At the end of the activity we will conduct a brief numerical survey of student satisfaction and benefit derived from the activity. We will solicit brief responses from the students, discuss the outcomes with experienced educators at the school, and have SPS volunteers discuss among themselves as to how things went and what could be improved between each visit.

Additionally, to evaluate the feasibility and difficulty of the interferometer design, we will hold a pilot version of the lab activity during an SPS general body meeting. SPS volunteers will guide Stony Brook underclassmen through the lab kits while emphasizing the physics at play. After the activity, we will discuss with the underclassmen to evaluate the strong and weak points of the lesson and iron out any kinks in the lesson plan or interferometer design.

Budget Justification

The budget will entirely be spent on materials to develop and fabricate ~20 new and improved interferometer kits. Including our remaining material from our 2023-2024 and 2024-2025 interferometer lab kits, we will have the means to manufacture approximately 30 quantum eraser kits, 20 with the new design. We aim for 30 so that schools will again be able to keep some kits for themselves and for follow-up activities. Our budget includes high quality linear polarizing paper from Edmund Optics, material to 3D print the body of each interferometer, and a bulk order of safe 1 mW red laser diodes alongside batteries to power them. New to this year's budget are retarder films (half-waveplate and quarter-waveplate film) from Edmund Optics for experimenting with and designing extension/"take-home" activities related to quantum computing and the Bloch sphere. These projects and demonstrations serve the dual purposes of deepening students' learning by engaging them with hands-on applications of the principles they'll learn in our seminars, while also proving to them: *Physics is fun!*