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

Marsh W. White Award Proposal

Project Proposal Title	Making Waves: a Hands-On Interference Lab for High School Students
Name of School	Stony Brook University
SPS Chapter Number	#6786
Total Amount Requested	$597.28

Abstract

Most students have never seen quantum phenomena in their daily lives, and therefore have difficulty grasping its counterintuitive nature. To build intuition and inspire interest in quantum physics, Stony Brook SPS proposes a hands-on guided lab activity for students to build Mach–Zehnder interferometers and witness interference and wave-particle duality firsthand.

Proposal Statement

Overview of Proposed Project/Activity/Event

Many schools across the United States feel underprepared and under-resourced to provide opportunities for students to sufficiently explore physics. This problem is particularly pronounced for fields of physics, such as quantum physics, that traditionally require specialized and expensive equipment to demonstrate. STEM students therefore have inordinate difficulty with this subject, having never seen quantum phenomena firsthand. This, in turn, inhibits the US's ability to produce a quantum-ready workforce. To expose high school students to tools used in real research experiments, build their quantum intuition early, and promote interest in further STEM education, volunteering Stony Brook SPS members will create lab kits and instructional plans for high school students to learn the principles of quantum physics and optics with their own hands.

We will host a series of one-day events at several high schools in the Stony Brook area. We have plans to host the activity at Longwood High School, and we are in the process of working out activities with other local high schools. Each event will have two components. The first will be an introduction to waves and optics using relatively familiar phenomena and simple tools like linear polarizers. This hands-on experience will give students physical insight into the abstract concepts of waves and vectors they learned in their math courses. The second component will be more DIY. First, we will use a prebuilt demo Mach–Zehnder interferometer to exhibit interference with the appearance of fringes with interactive demonstrations. Then, we will give students kits to make their own interferometers and explain their conceptual outline. Practiced SPS members will then circulate, giving students constructive guidance when they get stuck. Finally, once students have had a chance to see two beams of light combine to create dark spots, they will be able to use the polarizers from earlier to conduct a simple which-way experiment, where they will see a real demonstration of the wave-particle duality of light.

Our chapter has had extensive experience with science communication, tutoring, and STEM education. We have emphasized science communication through our general body meetings and the weekly Physics Cafés we've held for the past three years for students to practice presenting physics topics in lay language. Our Peer Mentorship program is entering its third year, so many of our members have plenty of experience responsibly encouraging younger students in their pusit of a physics education. Numerous of our general body members have served as TAs or student teachers, giving them educational experience. Several of our members are also involved with QuEST, the Quantum Education for Students and Teachers program, and have experience designing educational materials. In light of the success of our *Engaging High Schoolers in Electromagnetism* lab kit activity (facilitated by a 2023 Marsh W. White Outreach Award), our chapter strongly believes that we have the expertise and dedication necessary to carry out this proposal.

How Proposed Activity Promotes Interest in Physics

It is an unfortunate fact that some of the most interesting and exciting phenomena of physics—such as quantum superposition and wave-particle duality—are usually inaccessible to students and the general public. However, thanks to the efforts of Stony Brook SPS members in collaboration with QuEST, we can ameliorate this fact for high schools around Stony Brook. Our design for a low-cost, teenager-friendly interferometer will provide a real-life demonstration of these intriguing phenomena, and connect the abstract physics ideas to something students build with their own hands. 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.

Another unfortunate fact is the deficits and disparities in physics education resources across schools. Many schools, such as Longwood High School, are ill-equipped to provide extracurricular stimulation in traditionally less

popular fields, such as physics. Brilliant students who might thrive in physics never have the opportunity to explore the subject deeply. The Marsh W. White Award will enable our chapter to provide students with the encouragement needed to pursue physics further. Besides demonstrating an exciting realm of science students would otherwise have little exposure to, we will show students how fun it is to build their own instrument.

In today's rapidly advancing technological landscape, there is a growing need for a quantum-ready workforce. However, this is inhibited by the apprehension many people have towards the subject and its counterintuitive nature. Our lab kits will give students a taste of the quantum world, unveiling the subject and motivating them to pursue it further. They will also provide the unique opportunity for students to get hands-on experience with a tool, the interferometer, commonly used in both research and industrial settings in the field of quantum technology. In physics and other STEM fields, quantum physics is intimidating—we aim to show high schoolers: *quantum physics is for you*.

Plan for Carrying Out Proposed Project/Activity/Event

This year, several members of Stony Brook SPS are associated with an educational project at Stony Brook, Quantum Education for Students and Teachers (QuEST) [NSF Award No.: 2148467]. For their role on this project, these students are designing a low-cost Mach–Zehnder interferometer to demonstrate interference of light in a high school lab environment. SPS will make a series of lab kits and lesson plans based on this design. We will test and troubleshoot the lab kits and lessons by holding a pilot lab activity for Stony Brook Physics underclassmen.

After the success of our Electromagnetism Lab Kits last year, SPS will again hold this one-day lab activity at Longwood HS, using our established connections with the Vice Principal and two physics teachers. Additionally, we are in communication with Wellington C. Mepham High School, and Dr. Angela Kelly, associate director for the Institute of STEM Education at Stony Brook, who has put us in touch with the science directors of William Floyd, Smithtown, and Commack school districts about hosting events at their schools as well. Following the model of our activity with Longwood, each additional school will advertise the opportunity and come up with a list of interested students.

For each lab event, volunteers from our SPS chapter will travel to the high school, guide students through the activity, and intersperse quantum instruction throughout. Students who complete the lab kit will be allowed to keep the interferometer they built.

Project/Activity/Event Timeline

Longwood HS, which participated in our High School Outreach program last year, is enthusiastic about us hosting this activity at the school again. Besides Longwood, we plan to leverage our relations with Wellington HS and reach out to William Floyd, Smithtown, and Commack school districts to hold the activity at additional local schools and achieve a wider reach. Our timeline, modeled on our successful timeline last year, is as follows:

We will complete development of the lesson plan interferometer lab instructions by the end of December. By this point, we will finish ironing out logistical details with the high schools we will host the activity at. By the end of January, we will have assembled the interferometer kits. In February, we will host a general body meeting to pilot the lab and lesson plans with SPS general body members and Stony Brook underclassmen. We will incorporate feedback from this pilot and address any hiccups by the end of February. Additionally, we will build our demo interferometer this month. The outreach events will take place on weekdays from early March to late April, with specific dates to be determined. At the end of each event day, we will survey the participants and discuss with high school educators to evaluate if we met our goal of making optics approachable and exciting.

Activity Evaluation Plan

We will evaluate the success of our efforts with two quantitative and three qualitative metrics. For each high school at which we hold a lab activity, we will record the attendance and proportion of students who successfully built their interferometers, as well as a numerical survey of student satisfaction and benefit derived from the activity. Each day, we will solicit brief responses from the students, discuss the outcomes with experienced educators at the school, and debrief the SPS volunteers who were working with students to keep them motivated and along the right direction as they built their interferometers.

Additionally, to evaluate the feasibility and difficulty of the interferometer design, we will hold a pilot version of the lab activity during a SPS general body meeting. As we did last year for our Electromagnetism Lab Kits, SPS volunteers will guide 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 supplies for the projects to be completed by students and demonstrations to be performed by SPS members. A large portion of the budget will go to building a reliable and durable Mach–Zehnder interferometer, which will be reused for each event to demonstrate interference on a setup guaranteed to work. Having a functional demo is a critical requirement for this event, so students understand what they are trying to build and what phenomena they should expect to see. This also gives students exposure to research-grade optics. Additionally, having a study demo will give all students the chance to play with interference, even those who might have difficulty building their own interferometers.

Our budget proposal also includes materials to build 60 interferometer kits, for students to have the opportunity to build their own interferometer and gain experience with laser and mirror alignment and interference. Students will be allowed to keep their kits as a technical toy to produce interference whenever they want. The budget includes necessary materials to manufacture fully-silvered and half-silvered mirrors at a very low cost of $1.42 per mirror or $4.27 per interferometer as well as material to 3D print the template for the kits. 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!*