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

SPS Chapter Research Award Proposal

Project Proposal Title	The Fundial: Fostering Community Through Guiding Principles of Physics
Name of School	Benedictine University
SPS Chapter Number	3034
Total Amount Requested	$1720

Abstract

We propose to build a large sundial on campus at Benedictine University. The goal of this project is to demonstrate to the community how a sundial works and to encourage people to be aware of the daily and yearly motion of the Sun and other solar system objects. We also propose to live stream the sundial at all times. A live view of the sundial will be viewable across the world next to a local clock on a dedicated web page that we will construct.

Proposal Statement

Overview of Proposed Project

This project's chief objective is the construction of a three meter-wide circular sundial on the outdoor premises of Benedictine University, where SPS Chapter 3034 is located. A live camera feed will be established to broadcast the sundial on a live stream, accessible from the Benedictine University website. The mounted sundial and outdoor, all-weather camera system are the two components of the research project. Research questions to be addressed include the maximum attainable accuracy of the sundial, in addition to the feasibility of the Internet-equipped camera monitoring system with regards to its outdoor installation and the variable weather of Illinois.

The primary factor motivating the construction and broadcasting of the sundial is community outreach. The sundial will serve a multifaceted function as a gathering place on Benedictine University's campus that also can generate conversations about astronomy and raise scientific awareness among the many community members who visit campus. Even those who are unable to visit it in person will be able to observe the sundial at any time via an internet livestream, which serves to update the ancient technology for the modern era. Sundials work by casting a shadow in a direction corresponding to the Sun's current position in the sky, providing direct information about the rotation of the Earth and the position of the Earth in orbit. Aesthetically, sundials also serve as functional works of art: not only is there a sense of wonder in the fact that a sundial's accurate time reading is based entirely in mathematics and nature, but there can be beauty in the artistic forms of the constructed sundial itself. For all of the reasons above, the sundial will serve as an excellent tool for community outreach once completed. The end result of the project will include the sundial and camera system installed on the campus of Benedictine University, and a dedicated web page on the Benedictine University website from which the sundial can be viewed at any time.

As this project promises a gathering place that is both physical and virtual, founded around an object that simultaneously serves as a scientific measuring tool, a monument, and a work of art, it will greatly advance the mission of the SPS program by bringing science in the form of astronomy, mathematics, and physics into greater public visibility. Whether a student or anyone else visiting campus has little to no experience with science, is heavily engaged with the subject, or is somewhere in between, a sundial is a scientific implement that anyone on campus can appreciate. Similarly, at any location around the world, the sundial will be viewable at any time by live stream, so the impacts of this sundial's construction have potential to extend far beyond the campus of Benedictine University. As such, the sundial's function and appeal is on a universal level that supports the aims of the SPS.

Background for Proposed Project

Timekeeping has become an essential part of our society; we rely on watches, clocks, and calendars to delegate when we accomplish certain tasks. Despite advancements in technology that have made modern timekeeping devices possible, human civilizations have been keeping time for millenia. From sundials to pocket watches, hourglasses to digital clocks on a cell phone, timekeeping has clearly evolved.

The first known sundial to be constructed was found in Egypt and dates back to about 1500 BC, composed of two strips of stone[1]. Babylonians and Egyptians pioneered the rudimentary sundial, using moving shadows to allow citizens to split their day into two parts[1]. Later, when the ancient Greeks developed trigonometry, hour lines on sundials could be determined arithmetically, and the technology gained a level of sophistication previously unseen[2]. As time passed, sundials were constructed in many societies, eventually reaching Europe and later the Americas[1].

A variety of sundial constructions are possible; some types include vertical, horizontal, and analemmatic sundials, all three of which can be derived from the equatorial sundial, which is more simple[2]. At the core, a sundial consists of a gnomon, which casts the shadow, and the base, upon which the shadow is cast, and the positions of each time are labeled[2,4]. By knowing one's latitude and longitude and utilizing the equation of time for the season/month in which one reads the sundial, one can accurately read time from a sundial[2,4].

Our proposed work will add to the current knowledge base by providing a new sundial in our specific location of Lisle, IL. Each sundial needs to be properly positioned and measured to account for the differences in the sun's movement at any given point on the planet, which varies across the globe due to the Earth's axis of rotation and elliptical orbit[2]. Expanding knowledge of and preserving the beauty and relative simplicity of such a practical art form is important.

Expected Results

The primary results of the research project will be the assembled sundial and camera system, in addition to the web page at which a livestream of the sundial can be accessed. Secondary results will take the form of data related to the performance of the sundial and camera that are collected after the physical components of the project have been constructed.

The research project aims to test the reliability of the sundial and observe the sundial and camera system's resilience to weather conditions following its construction. The expected form of gathered data in this project will consist of accuracy values for the time measurements made by the sundial, in addition to qualitative data on the moderate-term durability of the sundial and camera system. It is the aim in constructing the sundial to maximize the accuracy and minimize the observed wear on the sundial.

We will also collect data on number of visits to the web page displaying the sundial and on community engagement in person with the sundial.

Description of Proposed Research - Methods, Design, and Procedures

Benedictine University has many cultural and artistic landmarks on campus that have influenced the campus's personality. Many of these pieces are religious, cultural, or historical. We wish to add a new addition to the campus that incorporates science and technology that blends with the other structures on campus. There is a plot of grass that we have been given permission to utilize in the middle of campus that is perfect for a sundial.

The sundial will be designed using AutoCAD. The sundial will be three meters in diameter and 15 centimeters deep. The hour lines for the sundial base are calculated using equation 1, where D is the angle from noon to the desired line. Here t is the time in degrees and ϕ is the latitude. With the tilt of the

earth and elliptical shape of earth's orbit around the sun, the sundial will need a time correction. With daylight savings and different parts of the world getting different positions of the sun at different times in the year; up to a 14 minute correction may be needed. This correction can be calculated using equation 4, and a chart for various points around the year will be provided to help viewers correct the time[5].

1. $\tan(D) = \tan(t) * \sin(\phi)$
2. $eqn_{tilt}(n) = (\pi/4) * -\tan^{-1}(\cos(tlt) * \tan((\pi/4)) * (720/\pi) * (\sin(2\pi * (n-81)/183))$
3. $(1440/361)*((360/\pi)ecc * \sin((360/366) * (n-2) * deg))$
4. $eqt(n) = eqn_{tilt}(n) + eqn_{Ecc}(n)$
5. $tlt=23.433°$
6. $ecc=0.016713$

We would first start by marking the ground with spray paint to indicate where the circle base of the sundial would go. This would be measured before sprayed. The area would then be dug one-half foot into the ground via a small excavator and lined with rebar. The concrete will then be poured into the lined area. While drying, 3-D printed concrete stamps will be put into the concrete that will create the informational pieces of the sundial base. The informational pieces of the sundial consist of the numbers that tell the time, the date of creation, and the officers and advisors involved. The concrete will be covered and dried overnight. The gnomon of the sundial will be 3-D printed and installed into the concrete base.

Once the sundial has been built, we can set up a solar powered camera that will livestream the sundial on the Benedictine University website. Registration with the North American Sundial Society could allow us to livestream on their platform as well.

Plan for Carrying Out Proposed Project

Benedictine University has provided us with the necessary space to build the sundial. Construction of 3-D printed materials will take place in the physics lab where SPS holds our weekly meetings. The SPS club, which has around twenty members, will be involved in the design and construction of the sundial. We also hope to collaborate with other clubs on campus such as the Engineers without Borders Club in the construction of the sundial and bring in the Art Club on campus to foster an aesthetic construction. The club secretary has previous experience in website management and will be the main web page engineer to facilitate its construction. Other members of the executive board have taken advanced physics classes which will provide unique insights into the construction and calibration of the sundial. The faculty advisor specializes in astronomy and will guide calibration of the sundial. Several members of the club have experience with 3-D printing which will allow for a collaborative effort.

Project Timeline

We plan to spend the initial stages of the project on community involvement, web page design and acquiring the necessary materials. The web page will be completed by February 28th, with key information on the history and function of sundials, the sundial's accuracy along with streaming capacity. The gnomon will be designed and fabricated by April 1st. The 3-D printed stamps to label the sundial will also be fabricated during this time, with all necessary stamps to be finished by April 7th, due to the time

consuming nature of 3-D printing and the limited machines available for this task. Concurrently we will hold meetings as a club and with the public to generate expertise and excitement for the sundial project. SPS members will review and confer on the mathematics involved and grow their knowledge of trigonometric practical astronomy; model sundials will be built during this phase to explore the best possible construction methods. The plan is to begin construction of the sundial in late April, but should this deadline be unachievable due to weather, we will begin construction of the sundial as soon as weather permits. The executive board members will begin compiling and finalizing the information for the interim report at the beginning of May, with a draft to be submitted to the faculty advisor for comments by May 15th in order to make the necessary changes and before submission on May 31st. The club will begin laying the concrete for the sundial early in May with the plan to have a completed sundial with a working livestream before the semester ends on May 7th. Data analysis will be conducted over the summer to determine precision and accuracy of the instrument. A contingency plan is in place to finish the sundial in late August should the proposed plan be undermined by weather. The first SPS meeting of the fall semester will be held at the sundial, with a focus on outreach and unveiling the new physics based art on campus. At this time we will apply for recognition with the North American Sundial Registry. Results and impact statements will be compiled through November 15th where a draft of the final report will be submitted to the faculty mentor for suggested revisions with the final version being submitted December 31st.

Budget Justification

The informational concrete stamps, model sundial and the gnomon will be fabricated onsite using the University's 3-D printers. The cost represents the cost of the 3-D printer materials. Our largest cost will be a cost to the University grounds department to use an excavator to clear the 3-meter diameter area for the base of the sundial; we budget $800 for this cost. We budget $200 for the camera with solar panels. We are considering a camera similar to the one linked here: https://tinyurl.com/yevhxmms. For spray paint we budget $50 for several cans of paint. For rebar we budget $20 and for concrete for the base we budget $150. We budget $100 for other hardware, including hardware to attach the gnomon to the base and to allow for corrections. We finally budget $250 for artistic additions, to allow items recommended by students of art to improve the aesthetics of the sundial. Our total budget for the project is $1720.

Bibliography

1. https://eaae-astronomy.org/find-a-sundial/short-history-of-sundials
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3. https://sundials.org/index.php/sundial-registry
4. https://eaae-astronomy.org/workshops/building-simple-sundials
5. https://peer.asee.org/sundials-make-interesting-freshman-design-projects.pdf