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An Experiment in the Earth Physics Leaning: Sunlight Observation for Determining Radius of The Earth

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A B S T R A C T

In the learning of the earth physics, sometime students got comfusing due to they cannot imagine how to determine the physical property of the earth such as, its mass, its volume and its diameter. This study was focused on how to use the sunlight for degermation of the earth radius through the simple experiment. In this study, an accurate and simple method have been introduced to the student on how to measure the earth radius. The experiment just used a camera and then the student started to determine the earth radius. In the end of the experiment student can explain how the sunlight can be used to determine the earth radius mathematically. They found that the radius of the earth is about 6243.04 km with a standard deviation of 13.70 km. The average results that is obtained by student is actually within 1.9% of the real value of the earth radius which is at 6371 km. This study shows that the real experiment is definitely able to show the real experience on how to determine the earth radius.

1. Introduction

In learning the Advanced Earth Physics subject, the Physics Education Study Program of the University of Riau, one of them is that students are faced with how to measure the finger of the earth. In general, students have problems imagining how to determine the radius of the earth. "It is very difficult to imagine how to determine the finger of the earth", is a sentence that often comes from students when asked about such things. The first person to measure the radius of the earth and is now considered a mathematician was the Greek, Eratosthenes (276–195 BC). In his discovery Eratosthenes used the distance between the Egyptian cities of Alexandria on the western side of the Nile Delta and Syene near Aswan in southern Egypt. By knowing the altitude angle of the Sun at each location, that is exactly one day apart. With this data estimate Eraosthenes was able to estimate the circumference of the Earth. Eratosthenes finally determined the radius of the Earth to be about 6317 km. The size of this radius is only about 1% smaller than

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the finger measured today with advanced technology, which is 6371 km (Eratosthenes, 2010).

After Eratosthenes had been around for so long, the technique of measuring the finger of the earth developed very rapidly. At this time, many other simple methods exist to determine the radius of the Earth. Google Earth is a method that various practitioners can feel easily measure the finger of the earth. However, the use of Google Earth is not actually felt, because Google Earth is the result of satellite photos made in three-dimensional form (Much Aziz & Atikah, 2014). However, there are some obvious ways that can be used to measure the radius of the earth. Gangadharan (2009) measured the finger of the earth by looking at the ocean from above the mountains. Meanwhile, Goodman (1993) determined the radius of the earth by rowing a canoe on a lake. French (1982) measured the radius of the earth by looking at a long horizon. Maybe there are more ways to determine the radius of the earth. All the methods that have been used are using the fact that the Earth requires one sidereal day to complete one full rotation, while sunlight is used as a reference (Philip Kristanto, 2000). The idea for this experiment was to reduce errors and be able to collect data in one location in a short amount of time.

The method discussed in this paper is basically similar to recording the time the sun sets over various levels in a tall building. While the radius and the method of calculating it has been known so far. This method is used to provide a deeper understanding of the Physics Education Students of Riau University in the Advanced Earth Physics course. The calculations rely on simple geometry and the results approximate the values accepted for the radius of the Earth.

2. Methodology

In this study, students involved were Physics Education Students of Riau University who took Advanced Earth Physics courses even semester of the 2017-2018 academic year. The lecture method used is the lecture method, followed by the demonstration method, namely demonstrating a video of calculating the radius of the earth. The application of the demonstration method is intended to clarify the meaning of the concept and show how to do something or the process of happening (Daryanto, 2010). After that students are given the task of calculating the fingers of the earth with their respective observations.

At the beginning of the lecture, students are given material about the characteristics of the Earth and the structures that make up the earth as shown in Figure 1. In the previous lecture, students were given an explanation of how the earth's surface changes shape from time to time, what causes the change in shape, what are the implications and benefits. After that, we discussed the characteristics of the earth.

Figure 1. General shape of the earth (Google Erath)

After an explanation of the characteristics of the earth, then a demonstration is given of how the radius of the earth is measured. Demonstrations were given directly using Globe for its small scale (Surdin, 2017). Then proceed by providing a video watch how to determine the finger of the earth by utilizing the sun's setting.

After the demonstration is over, students are asked to make observations on their own in the field in any place they feel is appropriate to do so. Students are divided into 7 groups, each group consisting of 5 people. Students are given one week to carry out their own experiments. The only equipment needed to carry out the experiment is the camera on their cellphone and by using a video playback software that can produce slowdown and beam analysis called ImageJ.

3. Results and Discussion

In the lecture process, a video demonstration of counting the fingers of the earth is given by utilizing the sun's setting (Abu Yazid et al, 2019). Figure 2 shows the shape of the earth and the rotation of the earth relative to sunlight.

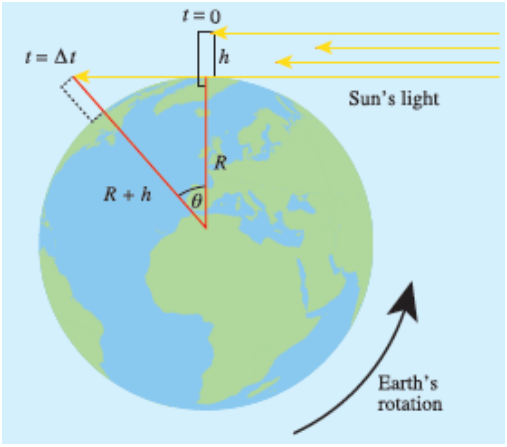

Figure 2. The shape of the earth and the rotation of the earth relative to sunlight

The concept of measuring the radius of the earth can be started from Figure 2. When t = 0, sunlight still shines on all buildings. But after a while a dark shadow will rise to the building until finally the top of the building is also dark. When the height of the building is known and the time of motion of the rays from bottom to top is also calculated from camera observations, this data can be used by knowing the size of the sidereal day to calculate the earth's rotation angle during that time interval. Mathematically it can be used:

$$\frac{\theta}{2\pi} = \frac{\Delta t}{1\ sidereal\ day}$$

$$\theta = \frac{\Delta t}{1\ sidereal\ day} 2\pi$$

The Pythagorean Theorem can be used to calculate the radius of the Earth, as shown in figure 2. From the values obtained we can use the Pythagorean theorem to produce a solution for R, the radius of the Earth.

$$\cos\theta = \frac{R}{R+h}$$

$$R = \frac{h\cos\theta}{(1-\cos\theta)}$$

Since θ will be very close to zero, and cos 0 = 1, the above equation can be simplified to:

$$R = \frac{h}{(1-\cos\theta)}$$

θ is calculated from θ = 2π (Δt / T), where T is a sidereal day, which is 23 hours, 56 minutes and 4.1 seconds (86 164.1 seconds) and □t is the time when the image appears on the building to the height h. Thus, the radius of the earth R can be calculated.

Demonstration

In the demonstration a tall building was chosen with a clear view between the horizon where the Sun is setting and the side of the building facing it. Two easily identifiable points were selected on the building to serve as reference points for the movement of the image. Demonstrations are carried out in class by playing videos which are the results of direct observations in the field by researchers. In the intended demonstration, all students paid close attention and observed carefully.

Student Experiment Task

For student experiment assignments, students were asked to do group experiments. One group consists of 5-7 people. In the experiment, students were

given the freedom to choose their preferred location. All groups of students chose a telecommunications tower as the building to be used in their observations. With this reason, the telecommunications tower has a fairly high height. In observations, students record the height of the light that will be observed from the reference height to the height they want. In calculating the height, they use a trigonometric approach to determine the height of the tower. For this purpose, students use angles as well as flat distances so that the tower height can be predicted. In determining the angle, students use a laser pointer so that the angle obtained is more accurate.

This experiment was carried out by students with observations several times because the problem faced was the difficulty of seeing the shadow rising from the bottom to the top of the tower. This is because the sunlight that is observed is less clear. Therefore, students conducted several experiments to ensure the accuracy of the data they obtained. However, students get results like table 1. The measurements taken by students are 1.9% different from the existing measurements, namely 6317.

Table 1. The radius of the earth calculated

Group	Earth Radius
1	6252.31
2	6241.24
3	6222.72
4	6241.42
5	6262.13

4. Conclusion

In this research, it has been found that the radius of the earth does not match the radius of the earth that is referenced. From the results of the experiments carried out there is about 1.9% difference from the calculations that have been obtained at the international level. This difference is due to the fact that observing sunlight is quite difficult because the sunlight received by the building is quite dim.

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