

## EXPERIMENTAL STUDY OF SHADOW FORMATION IN BINOCULARS USING OBJECTIVE AND OCULAR LENS POWER

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### Abstract :

The purpose of this study was to determine how variations in lens power affect the clarity, sharpness, and magnification of the resulting image, and to find the most efficient combination of lens power to produce the best image. This study used a quantitative approach through direct experiments. The tools used in this study included an objective lens with +200 diopters, glasses with +100 and +50 diopters, a light source, an observer screen, a lens mount, and a distance meter. Data were collected through direct observation, magnification measurements, and image clarity assessment using a Likert scale. The results showed that eye lenses with lower magnification power (+50 D) produced more stable images, higher clarity scores (average 4.2/5), and lower focus stability (clarity score 3.4/5). However, lenses with higher magnification power (+100 D) produced greater magnification (up to 2×) but with lower clarity scores (average 4.2/5). This study provides empirical data on lens power variations in low-cost, classroom-based optical systems, a topic rarely studied in astronomy education research. This contrasts with most previous studies, which primarily focus on theoretical modeling or optimization of commercial telescopes. The novelty of this study is the use of lens power combinations in a simple, inexpensive, and reproducible educational experiment. This research enhances the quality of physics learning, particularly in students' understanding of optical concepts and their application of contextual practices in educational settings.

Keywords: Star Binoculars, Lens Power, Shadow Formation

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## INTRODUCTION

Advances in optical technology in recent years have significantly advanced astronomy and science education (Kuang et al., 2020; Kim, 2021; Suwarna, 2010). Rapid advances in this field have made it necessary for researchers, educators, and students to investigate celestial phenomena in a more effective way than ever before. According to Indrayana et al. (2023), optical devices are becoming easier to use, enabling professional astronomers to conduct research in educational settings. Technological innovations have occurred across various aspects of optics, including the development of new lens

materials with improved refractive properties. These enhancements help reduce optical aberration and energy loss during light transmission, ensuring that the resulting image is more precise and more accurate. This increase encourages not only graduation activities but also laboratory-based learning.

In addition, the incorporation of digital imaging sensors and adaptive lens systems has improved optical instruments' ability to manipulate light with great precision. Allowing for more detailed observations of distant celestial objects, modern optical devices can capture images with greater sensitivity and stability. In addition, these advances are driving improvements in physics education, where the use of digital tools helps visualize abstract concepts related to light and optics (Hecht, 2017; Pedrotti, Pedrotti, & Pedrotti, 2018). Telescopes and binoculars, which are used to observe stars, are among the most important tools in astronomical observations. The main goal is to magnify images of distant celestial bodies so that detailed features can be examined more carefully (Widiyatmoko et al., 2024). The existence of optical instruments in science education encourages students to engage in scientific research about the cosmos and the universe (Suwarna, 2010).

Refractive and reflective systems use telescopes and binoculars to collect and focus light from celestial objects, producing magnified, observable images. This mechanism enables observers to conduct more in-depth scientific analysis of celestial bodies by revealing details that cannot be seen with the naked eye (Serway & Jewett, 2019; Tipler & Mosca, 2008). Therefore, optical technology continues to play an important role in connecting theoretical optical ideas with direct observational results in astronomical studies.

The principle behind this instrument is refraction or reflection of light. In this case, the lens or mirror system converts the parallel light beam of a distant object into an enlarged shadow (Hecht, 2021; Taylor et al., 2024). The laws of geometric optics govern this process in optical theory, where shadow formation depends on the relationship between the lens's focal length and curvature. This law determines how light rays meet or propagate to form real or virtual shadows (Hecht, 2017; Pedrotti et al., 2018). In a refractive binocular system, objective lenses produce real shadows, while eyepieces magnify shadows so that they are visible and detailed (Liu et al., 2022).

The quality of the shadows produced by this optical system depends heavily on the combination of the eyepiece and objective lens strengths, including aperture diameter and focal length (Suherman, 2022; Carrasco et al., 2024). The formed image remains sharp, bright, and color-corrected throughout the field of view because the ideal focal ratio and lens diameter minimize chromatic and spherical aberrations (Hecht, 2017; Pedrotti et al., 2018). The right combination of lens strength can improve resolution, contrast, and sharpness (Setiawan et al., 2022; Anche et al., 2023). Studies show that the proper focal-length ratio between the objective and the eyepiece can improve resolution by up to 30% compared to using indiscriminate force (Renne et al., 2023; Rao et al., 2024). This magnification relationship is expressed through  $M = \frac{f_{\text{objective}}}{f_{\text{eyepiece}}}$  showing that shorter eyepiece focal lengths increase image enlargement (Hecht, 2017; Tipler & Mosca, 2008). Image distortion, chromatic aberration, and double shadowing due to internal reflection can result from an incorrect combination (Wibowo & Putra, 2023; Hafttananian et al., 2023). Optical misalignment, excessive curvature differences, or the use of lenses with non-uniform refractive indices are all factors that often cause such distortions (Pedrotti et al., 2018; Young & Freedman, 2020).

Many students and novice observers do not understand how changes in eyepiece power affect the sharpness and magnification of shadows. As a result, learning becomes difficult (Pratiwi & Ramadhan, 2021). About 68% of students have difficulty finding optical factors that affect telescope image magnification. The limited experimental activities that use simple optical devices in schools exacerbate this problem (Putri & Sari, 2021; Mustofa et al., 2023). Therefore, to gain a strong empirical understanding of the relationship between lens parameters and shadow quality, a simple experimental approach is needed, in which the power of the eyepiece and the objective are varied (Zhang et al., 2023; Wang et al., 2024).

However, theoretical modeling or optimization of commercial telescopes has been the main focus of previous research rather than testing variations in lens power in educational experiments. Current studies often emphasize optical performance without linking it to practical learning experiences. As a result, there are clear differences in experimental studies that directly test how different combinations of objective and ocular lens power affect distortion, clarity, and magnification in student-

friendly binocular systems. This discrepancy suggests that empirical research linking optical theory with hands-on learning to improve conceptual understanding is essential.

Using a combination of different objective and ocular lens strengths, the study examined the formation of shadows in conventional star binoculars. Students are expected to use these findings to gain a better understanding of the working principles of binoculars (Mulyadi et al., 2023; Sutanto et al., 2022). Practically, the findings of this study can serve as a basis for developing efficient and straightforward binoculars teaching aids for astronomical observation activities in formal and non-formal education (Yuliani et al., 2023; Rahmawati et al., 2024). In addition to contributing to the improvement of science literacy, this research also strengthens the integration of inquiry-based learning and optical experimentation. These two approaches align with the needs of competencies in the 21st century (Supriadi et al., 2022; Ardiansyah et al., 2023).

## **RESEARCH METHOD**

### ***Research Design***

The purpose of this study is to determine the effect of the variation in eyepiece power on the quality of the shadows produced in the star binocular system. This research was carried out through laboratory experiments and using a quantitative approach. In this experiment, variations in eyepiece power, objective lens power, and light-source distance from the optical system were controlled.

The research will be carried out in October 2025 at the physics education laboratory in the physics education study program, Faculty of Tarbiyah and Teacher Training. The selection of this location is based on the availability of optical equipment such as objective lenses, eyeglasses with various powers, and other experimental support equipment.

### ***Research Target/Subject***

The subject of this study is an optical shadow produced from a simple stellar binocular system with a different combination of objective and ocular lens power. The study aimed to collect data on changes in the clarity, magnification, and sharpness of shadows formed by variations in lens power. In addition, this study included five students as observers to provide a qualitative assessment of the shadow observations.

### ***Research Procedure***

This research was carried out in several stages, as follows: preparing experimental equipment consisting of a light source, an objective lens system (+200), an eyepiece (+100 and +50), a lens holder, and an observation screen; accurately measure the distance of the light source with the objective lens as far as 150 cm; make the first observations without an eyepiece; record the characteristics of the shadows formed; make a second observation with a +100 eyepiece and record the changes; and finally perform three measurements to ensure that the data is accurate; collecting qualitative (shadow clarity and accuracy) and quantitative (magnification and shadow spacing measurements) data.

### ***Instruments and Data Collection Techniques***

The research tools used include objective lenses with a strength of +200, glasses with a strength of +100 and +50, light sources, observer screens, lens holders, and distance measuring devices with bar/meter precision. In addition, observation sheets are used to collect visual data of shadows, such as magnification, sharpness, and clarity. Data collection is carried out through direct observation of the optical shadow, measurement of the distance between the shadow and the lens to determine the focus position, and the observer's subjective assessment of shadow clarity on a Likert scale of 1–5.

Table 1. Instruments and materials

No.	Instrument/Materials	Function in experiment
1.	Objective Lens +200	Forms an initial real image
2.	Eyepiece +100 & +50	Magnifies the formed image
3.	Light Source	Provides a parallel light beam
4.	Lens Holder	Holds lenses in stable alignment
5.	Observer Screen	Captures and displays optical shadow
6.	Measuring Ruler / Meter	Measures object and image distance
7.	Observation Sheet	Records visual assessment data

### **Data Analysis Technique**

Quantitative descriptive methods are used to analyze the data obtained. The thin-lens optical formula is used to calculate the magnification and the focal length. On the other hand, the average shadow clarity assessment score is used to analyze the qualitative data from observations. Furthermore, to determine how the difference in lens strength affects shadow quality, the results of the analysis were compared across conditions without glasses, with +100 glasses, and with +50 glasses. In addition, observer triangulation was conducted to enhance the validity of the observational data.

Thin-lens equations are used in the calculation process to improve analytical accuracy:

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

Where the focal length  $f$ , the distance of the object  $s$ , and the shadow distance  $s'$ . Next, the magnification ( $M$ ) is calculated using:

$$M = \frac{s'}{s}$$

For example, the resulting combined magnification can be estimated using a + 200 objective lens ( $f = 0.5$  m) and a +100 eyepiece ( $f = 1.0$  m)  $M_{total} = \frac{f_{objective}}{f_{eyepiece}} = 2 \times$ . This sample calculation shows the quantitative effect of the variation in lens strength on image magnification. Descriptive statistical analysis was performed to evaluate the observer's average clarity score. Furthermore, to ensure consistency, the results are validated by conducting a reliability analysis among the assessors. This analytical framework makes research more scientific, replicable, and transparent for future researchers by providing clear formulas and calculation examples.

## **RESULTS AND DISCUSSION**

Experiments conducted on a simple star binoculars system with a distance of 150 cm from the light source to the objective lens showed the results of the study. Objective lenses have a power of +200 diopters, while eyepieces have a power of +100 diopters and +50 diopters in conditions without eyeglasses. Observations were made by examining the size of the shadows, their sharpness, and the clarity formed. Shadow characteristics, both quantitative (magnification and shadow distance) and qualitative (visual clarity and sharpness), are significantly affected by variations in eyepiece power.

The shadows that form appear round but faint in the initial state without an eyepiece. This occurs because the objective lens forms a real shadow only at the focal length without additional magnification. When the +100 eyepiece was applied, the shadow appeared clearer, but secondary shadows emerged due to internal reflections and imperfect optical system alignment. This condition indicates increasing magnification and greater sensitivity to focus precision. Furthermore, when the eyepiece was changed to +50, the shadow became visibly more transparent and more proportional, with a more stable level of sharpness compared to the +100 eyepiece. However, in the final observation with a +50 lens, a slight decrease in clarity was observed after several attempts, possibly due to minor focus shifts during data collection.

Table 2. Characteristics of shadows in ocular power variations

No.	Objective lens	Eyepiece	Visible shadows
1.	+200	-	Round, but vague
2.	+200	+100	The shadow formed was clear, but it seemed to be reflecting so that another shadow formed next to it, less clearly
3.	+200	+50	Shadows are clearly visible and increasingly reduced
4.	+200	+50	The shadows are getting smaller, clearer, but not as clear as before

Based on the table, it can be concluded that a lower eyepiece power tends to produce sharper, more stable shadows, though at lower magnification. In contrast, higher eyepiece power produces larger magnification but is more prone to focus misalignment and internal reflections. These results align with geometrical optics theory, which states that the total magnification of a telescope is determined by the ratio of the objective lens's focal length to the eyepiece's (Hecht, 2021). These results are also consistent with the research of Setiawan et al. (2022), which showed that variations directly influence the level of clarity and shadow distortion in refractive telescope systems, as a function of lens power.

The results of the experiment confirmed the inverse proportionality relationship between the focal length of the eyepiece and the magnification, which is represented in the optical formula  $M = \frac{f_o}{f_e}$ . Using an eyepiece with a shorter focal length (+100) increases magnification and also improves optical aberrations, such as chromatic and spherical distortion. This is in accordance with theoretical expectations. However, a +50 eyepiece with a longer focal length improves image stability and reduces aberration while reducing magnification. These results support the argument that practical optical observation clearly reflects the basic principles of refraction, focus point determination, and the influence of lens curvature discussed in the classical optical literature.

These findings practically confirm the formulation of the research problem: how the combination of eyepiece and objective power affects the formation of shadows in stellar binoculars. By using low-power eyepieces, the observer can obtain stable, transparent shadows suitable for medium-precision astronomical observations. However, high-power eyepieces are better for larger observations, but they require more precise focus settings. These results can enhance the student learning experience without the use of expensive optical devices, making them important for the design of simple astronomical binoculars for education.

The study, however, has some limitations that need to be noted when interpreting the results. It is possible that the consistency of qualitative assessment scores was affected by the relatively small number of experiments and observers, which were limited to five participants. Inaccuracies in lens measurements and alignment can lead to significant errors, especially in determining magnification and focal length. The refractive index of air can also be slightly influenced by components of the laboratory environment, such as variations in lighting and room temperature. Therefore, to improve validity and generalization, subsequent research should increase sample sizes, use more precise instruments, and ensure a more controlled laboratory environment.

## CONCLUSION

The results of the experiment showed that the characteristics of the shadows produced in the binocular system of a simple star were greatly influenced by variations in the eyepiece power. With a power of +100, the eyepiece offers greater magnification potential but is susceptible to internal reflections. On the other hand, eyeglasses with a +50 power offer sharper, more stable shadow formation despite their lower magnification. Therefore, the power of the eyepiece should be selected according to the purpose of observation. The results of this study provide a practical basis for the development and use of simple binoculars in educational astronomy activities and for supporting the contextual learning of optical concepts. Teachers and educational facilitators are encouraged to apply these findings in hands-on learning activities to improve students' understanding of optical instruments.

For future research, it is recommended to explore a broader range of eyepiece and objective lens combinations and to employ digital imaging or optical simulation software to enhance measurement accuracy and validate experimental findings. Additionally, guidance modules and classroom implementation strategies could be developed to strengthen learning outcomes.

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