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Preface

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PREFACE

International Seminar on Physics and Its Application (ISoPA) 2025 Surabaya State University on "Innovations and Challenges in Physics and Physics Education for a Sustainable Future"

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We proudly present the International Seminar on Physics and Its Application (ISoPA) 2025, Department of Physics, Universitas Negeri Surabaya (Unesa). This year, ISoPA, held on 26 July 2025 in Surabaya, is an essential event in our academic calendar. In our big theme, " Innovations and Challenges in Physics and Physics Education for a Sustainable Future," we try to explore the potential and challenges faced in achieving sustainable development through physics and physics education. The event was held via ZOOM meeting to facilitate ISoPA participants from within and outside the country. Participants are also unrestricted by time, accommodation, and other activity agendas.

The success of ISoPA 2025 will only be possible with valuable contributions from various parties. We are very grateful to our four keynote speakers; Prof. Dr. Michael Walter, Prof. Dr. Eko Hariyono, M.Pd, Assoc Prof. Felipe Hernandez-Rodriguez, Ph.D., and Prof. Dr. Akimitsu Hatta, who have provided in-depth insight into the development of physics and physics education in the Society 5.0 era. Thank you also to the Vice rector in the field of Planning, Development, Cooperation, and Information and Communication Technology: Prof. Dr. Dwi Cahyo Kartiko, S.Pd., M.Kes., who gave an inspiring opening speech.

The event was held in two sessions: plenary and parallel session. The plenary session presented four keynote speakers. The parallel sessions were attended by invited speakers and authors presenting their papers and held in ten breakout room groups. As a scientific forum, ISoPA 2025 was attended by more than 500 participants consisting of students, teachers, lecturers, engineers, and practitioners who participated both as presenters and participants. The ISoPA 2025 aims to share ideas and knowledge and build collaboration. We received 82 papers selected for publication in the Journal of Physics: Conference Series with a scope of physics and related fields. In this volume, we accepted 65 papers for publication after fulfilling the scope, checking for originality, and conducting peer review. We hope this event can be a starting point for welcoming global developments. Besides, the publications packaged in this seminar will further strengthen the existence and reputation of the physics department as an educational institution that is superior in scientific publications at national and international levels. The research results must be disseminated widely to be scientifically valuable and provide practical value to society.

Physics stands at the heart of technological progress. As a fundamental science, it enables breakthroughs that power modern industry, from advanced materials and energy systems to data-driven instrumentation, and earth science. Equally physics education is a vital education, which must cultivate not only conceptual mastery but also the twenty-first-century competencies of creativity, critical thinking, communication, and collaboration.

This seminar, themed “Innovations and Challenges in Physics and Physics Education for a Sustainable Future,” brings together researchers, educators, students, and industry partners to share recent advances and reflect on the hurdles ahead. The contributions in this volume span experimental and computational physics, green and smart technologies, instrumentation and sensing, as well as pedagogical frameworks, assessment strategies, and technology-enhanced

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learning. Collectively, they underscore how research and education in physics can accelerate progress toward the Sustainable Development Goals (SDGs): affordable and clean energy, quality education, sustainable cities and communities, responsible consumption and production, climate action, and beyond.

We hope the discussions and findings presented here will inspire new collaborations, inform evidence-based teaching and program design, and spark translational research that bridges laboratories, classrooms, and communities. By aligning scientific rigor with societal relevance, we can strengthen the pipeline of future physicists and educators who will design solutions for a more just, prosperous, and sustainable world.

On behalf of the Organizing Committee and Editorial Team, we extend our sincere gratitude to the keynote and invited speakers, session chairs, authors, reviewers, and participants whose expertise and dedication made this event and its proceedings possible. We also thank our institutional partners and sponsors for their unwavering support. We look forward to welcoming you to our next seminar and to continuing this shared journey of inquiry, innovation, and impact.

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Descriptions	**Deadlines**
Full paper Submission Duedate:	May 4th, 2025
Notification of Acceptance:	June 6th, 2025
Final Revision Due:	July 18th, 2025
Conference Day:	July 26th, 2025

Keynote Speakers

Prof. Dr. Michael Walter	(University of Freiburg, Germany)
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Peer Review Statement

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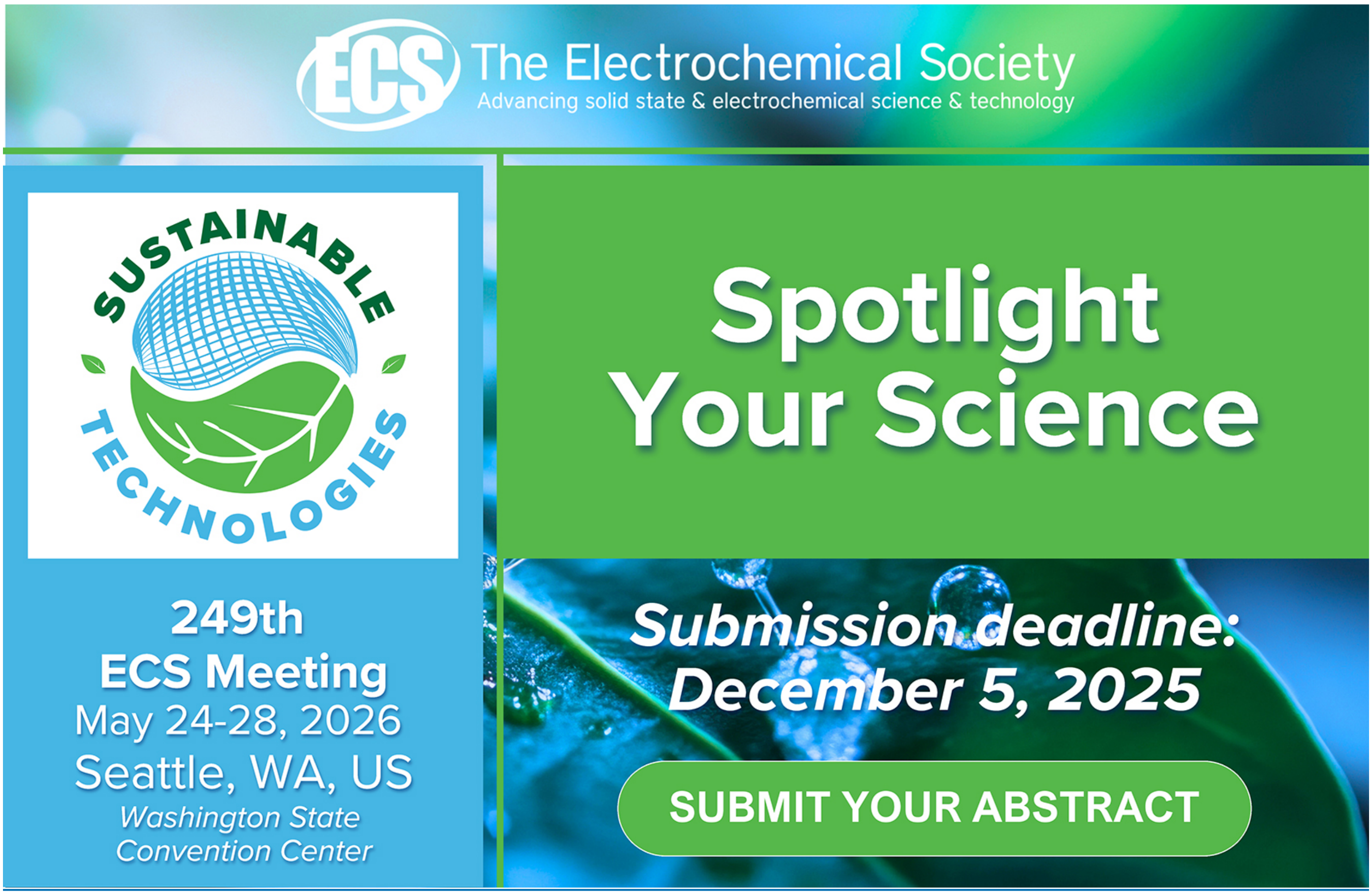

Peer Review Statement

All papers published in this volume have been reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Double Anonymous
- **Conference submission management system:** Morressier
- **Number of submissions received:** 84
- **Number of submissions sent for review:** 78
- **Number of submissions accepted:** 63
- **Acceptance Rate (Submissions Accepted / Submissions Received × 100):** 75
- **Average number of reviews per paper:** 1
- **Total number of reviewers involved:** 30
- **Contact person for queries:**
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Arduino-based measurement of liquid refractive index

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Arduino-based measurement of liquid refractive index

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Abstract. The refractive index of liquids has been measured using an Arduino-based system. This setup consists of a light source, a spherical flask filled with the test liquid, a light sensor, and an Arduino that controls sensor motion and records light intensity data. The focal point of the lens formed by the liquid-filled flask is determined by analysing the light intensity profile. The refractive index is calculated based on the radius of curvature and the focal length. Water and ethanol refractive indices were measured to be 1.33 ± 0.01 and 1.35 ± 0.01, respectively, consistent with published values.

1. Introduction

Arduino-based instruments have been widely used in recent physics experiments due to their affordability and compatibility with various sensors. Çoban and Erol used an ultrasonic distance sensor and an Arduino to track moving objects [1], Lin et al. measured acceleration using Arduino-controlled timing mechanisms [2], at the same time Mendes et al. determined the speed of sound using a simple Arduino-based setup [3]. An Arduino-based setup has been used to investigate gas laws [4], to study diode characteristics [5]. The inverse-square law of illumination has been explored using a light sensor connected to Arduino [6].

In a previous article, the refractive index of a liquid was measured using a photo analysis method [7]. A spherical flask was filled with the liquid, and two parallel laser beams were directed toward it. The focal length was found by analyzing the light path from the lens using photo analysis. However, aligning the laser beams and recording the light path accurately was a key challenge in that setup.

To simplify this process, an Arduino-based system was developed to find the focal point directly by tracking light intensity. A standard white light replaces the lasers, and the light sensor's motion and data collection are automated. This setup is more practical and designed to support computer-based experiments for students.

2. Materials and Method

The experimental apparatus (see Figure 1) includes a light source producing parallel beams, a spherical flask containing the test liquid (serving as a lens), a photodiode-based light sensor, and an Arduino-controlled linear motion guide with a stepper motor. The flask's height and position are adjusted so the light beam passes through the lens center.

The light sensor, mounted on the *Makeblock* linear guide, uses a voltage divider circuit and a potentiometer. The Arduino Uno controls sensor movement and records measurements.

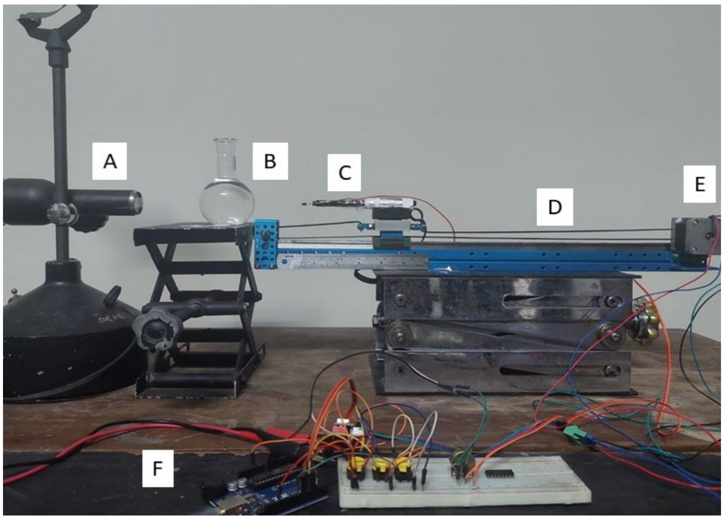

Figure 1. Experimental setup. A. Light source, B. Spherical flask, C. Light sensor, D. Linear motion guide, E. Stepper motor, F. Arduino and breadboard model.

Figure 2 shows the Arduino configuration. A *Nema 17* stepper motor with 5% step accuracy is powered by an external supply and controlled using an A4988 motor driver. Three buttons on the breadboard are used to move the sensor forward, backward, or stop its motion. The light sensor is built with a photodiode and a potentiometer mounted on the breadboard. In this configuration, the potentiometer voltage indicates light intensity, which is presented in arbitrary units (a.u.).

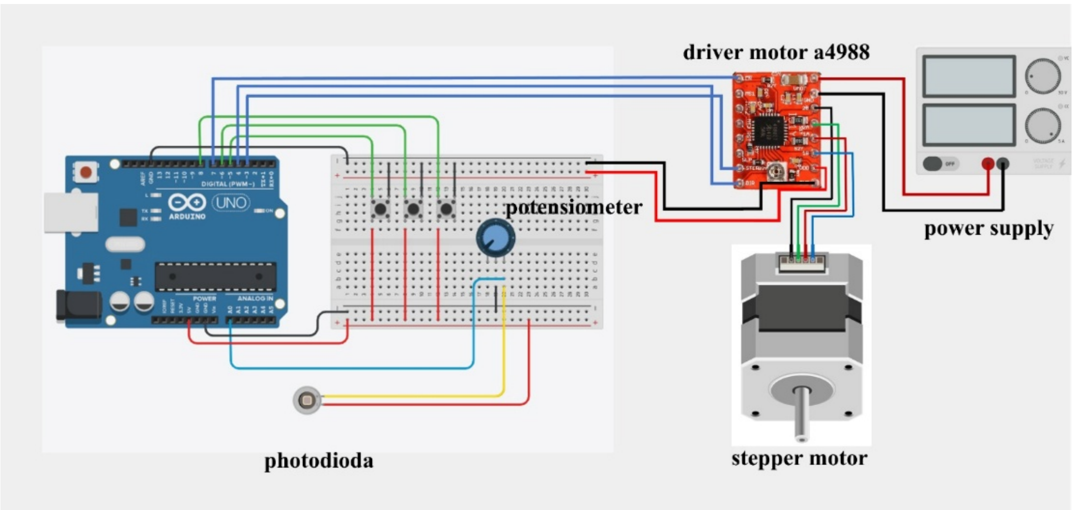

Figure 2. Arduino configuration.

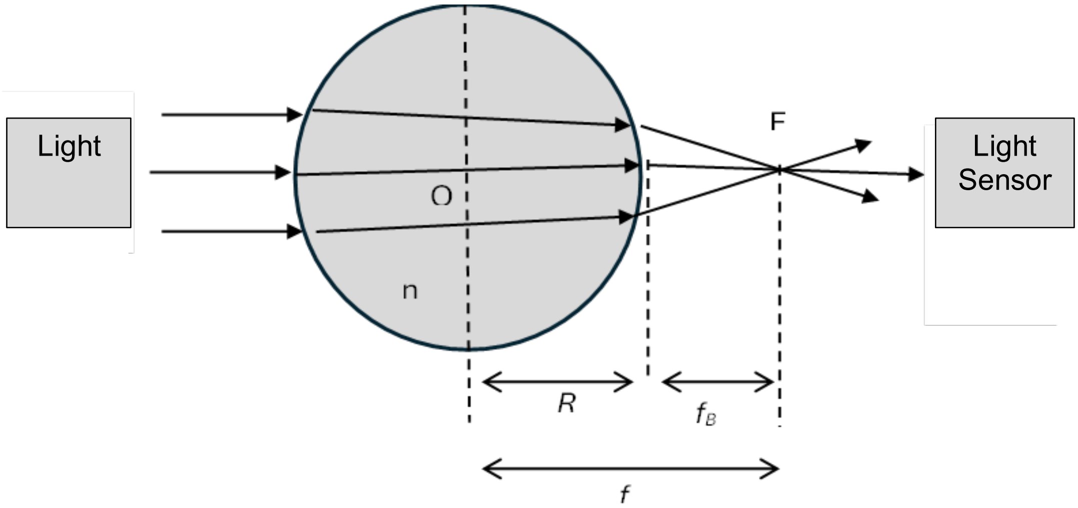

Figure 3. The experimental setup consists of a light source, a light sensor, and a spherical lens with the center of the lens at O, the focal point F.

The lens's radius of curvature is R. In this setup, the spherical flask acts as a lens with a thickness of $d = 2R$, as shown in Figure 3. The liquid under investigation in the flask has a refractive index n. If the lens is in the air, the lens's focal length f is given by Santosa [7]:

$$f = \frac{n}{2\,(n-1)}\ R \tag{1}$$

As shown in Figure 3, the distance between the focal point (F) and the lens surface is the back focal length (f_b):

$$f_b = f - R \tag{2}$$

or

$$f_b = \frac{(2-n)}{2\,(n-1)}\ R \tag{3}$$

From Equation (3), the lens's refractive index becomes

$$n = \frac{2 + 2\,\frac{f_b}{R}}{1 + 2\,\frac{f_b}{R}} \tag{4}$$

Based on Equation (4), the refractive index (n) can be determined by measuring the back focal length (f_b) and the radius of curvature (R).

A vernier calliper is used to measure the radius of curvature. The back focal length f_b is determined by tracking the position of the focal points. Initially, the light sensor is placed right next to the surface lens as a reference. The sensor position is perpendicular to the principal axis. Subsequently, the light sensor is moved along the principal axis to obtain the light intensity profile. The focal point is then determined from the position of the maximum recorded light intensity. Before making measurements, we must obtain the step motor calibration factor regarding distance. This factor is then used to convert the step data acquired from the Arduino into a distance measurement.

3. Results and Discussion

Our Arduino-based system is designed to determine the lens' focal length formed by a spherical flask and calculate the refractive index of the liquid from that. Based in Figure 3, we first inspect the location of the focal point. This is done by moving the light sensor along the principal axis and recording the light intensity at each position to generate a transmitted beam profile.

The sensor movement is controlled by a stepper motor, and its position is recorded in discrete steps. A calibration was performed to convert these steps into actual distance measurements, as shown in Figure 4. The system demonstrates a linear relationship between the step count and physical displacement, allowing distance to be reported in centimetres.

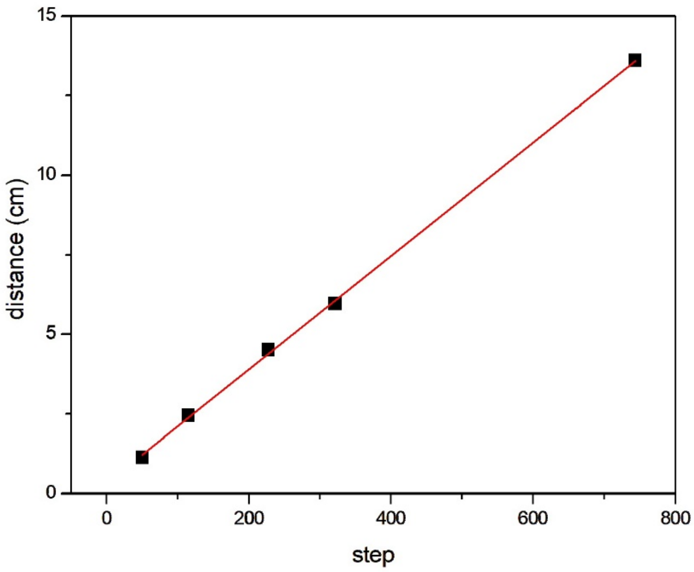

Figure 4. Calibration of the sensor's movement. The line is the best-fitting data.

This system obtained light intensity profiles for lenses formed by flasks filled with different liquids. For a flask with a radius of curvature of 3.1 cm, the profiles are shown in Figure 5. The flask was filled with water (red squares) and ethanol (blue squares). The resulting intensity profiles reveal a clear maximum, indicating the focal point. The location of this peak varies depending on the liquid used. This behavior shows that the medium affects the focal length. Equation (3) shows that the back focal length depends on the refractive index and the radius of curvature. A larger refractive index results in a shorter back focal length. Water produces a longer back focal length than ethanol, indicating that its refractive index is smaller than that of ethanol.

Figure 5 shows that the flask with a radius of curvature of 3.1 cm filled with water gives a back focal length is 3.04 cm. Using Equation (4), this corresponds to a refractive index of 1.33. Additional measurements were made using flasks with different curvature radii. The summarized results in Table 1 present that a larger radius will extend the focal length, as expected from Equation (4). It indicates a direct relationship between the focal length and the radius of curvature [7]. From Table 1 we obtained the average of refractive index of water, and its standard deviation was 1.33 ± 0.01.

Table 1 shows that the refractive index of water is consistently around 1.33. These results are in accordance with published standard database [8], measurement using a Michelson interferometer [9], and a simple method using a beaker [10]. Our results confirm the reliability of this system for locating the focal point and calculating the refractive index.

Similar measurements were performed using ethanol. The results are presented in Table 2. The average refractive index and its standard deviation were 1.35 ± 0.01 from three measurements. This result is consistent with other studies [9,11]. Kachiraju and Gregory show the refractive index of ethanol is 1.360696 ± 0.000001 [9].

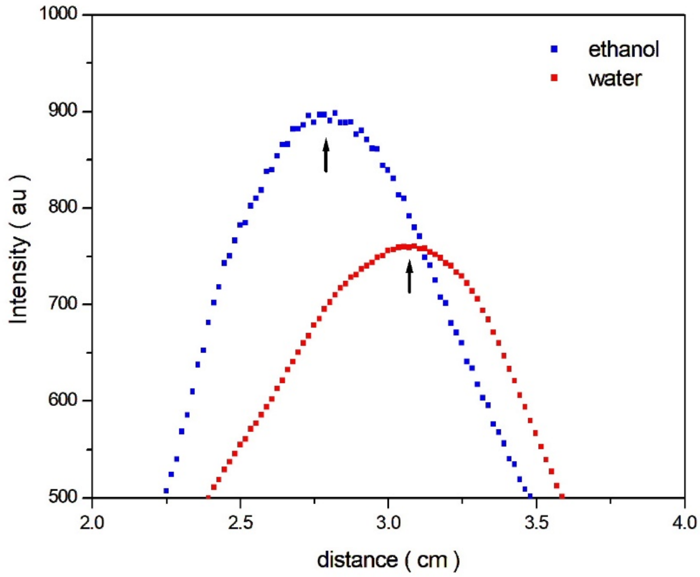

Figure 5. Light intensity profile of a lens with a radius curvature of 3.1 cm filled with water (red) and ethanol (blue).

Table 1. The experimental result for the flask filled with *water* obtained from the different radii of the flask.

R **(cm)**	f_b **(cm)**	***f*** **(cm)**	***n***
3.1	3.04	6.04	1.331
4.2	4.12	8.27	1.335
4.9	5.25	10.15	1.318

Table 2. The experimental result for the flask filled with *ethanol* obtained from the different radii of the flask.

R **(cm)**	f_b **(cm)**	***f*** **(cm)**	***n***
3.1	2.75	5.75	1.353
4.2	2.78	7.93	1.354
4.9	4.53	9.4	1.351

Figure 5 shows that the light intensity profile has a distinct peak, essential for locating the focal point. However, this peak appears broadened in some cases, introducing uncertainty into the position measurement and, consequently, the refractive index calculation.

In both cases of refractive index measurement, water and ethanol, the measured values align well with known values, demonstrating the method's validity. This experiment indicates that an

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Arduino-based setup can effectively investigate the properties of lenses formed by spherical flasks. It provides a method for students to observe the formation of focal points and study how the focal length is affected by the radius of curvature and the refractive index

Conclusion

This experiment presents a suitable method for measuring the refractive index of liquids using an Arduino-controlled system. The setup facilitates an exploration of basic lens principles and yields reliable results consistent with established values. Its simplicity and affordability make it is appropriate for an educational laboratory.

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