Вісник Харківського національного університету імені В. Н. Каразіна. Серія «Фізика». Вип. 42, 74-78 (2025)
Journal of V. N. Karazin Kharkiv National University. Series Physics. Iss. 42, 74-78 (2025)
DOI: 10.26565/2222-5617-2025-42 ISSN 2222-5617 (Print)

Original article
In print article
https://doi.org/10.26565/2222-5617-2025-42-10
UDC 535.4, 53.03, 378.147
PACS numbers: 42.25.Hz, 07.05.Rm, 01.50.My

USING WOLFRAM MATHEMATICA SOFTWARE ENVIRONMENT TO PROCESS THE RESULTS OF THE LABORATORY WORK "NEWTON'S RING"

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Received on April 7, 2025. Reviewed on May 20, 2025.
Accepted to publications on May 22, 2025.

This article deals with the urgent problem of introducing modern information technologies into the physics workshop, which increases the efficiency of the educational process and contributes to the formation of students' research competencies. The aim of the study is to analyze the capabilities of the Wolfram Mathematica software environment for processing and visualizing the results of interference experiments on the example of the laboratory work "Newton's Rings". The research methods include theoretical analysis of interference phenomena, computer modeling in the Wolfram Mathematica software environment, and the use of interactive demonstrations of the Wolfram Demonstrations Project. An algorithm for processing experimental data is proposed, which allows the automation of calculations and improves their accuracy. The results of the study are presented in the form of a mathematical model of Newton's rings, which provides a visualization of the interference pattern and allows studying the dependence of its characteristics on various physical parameters of the system. Methodical recommendations for integrating Wolfram Mathematica software environment into a laboratory physics workshop have been developed. It is proved that the use of this software contributes to the development of skills in working with modern software tools, stimulates students' research activities, and provides interdisciplinary links between physics, mathematics, and computer science. The implementation of the proposed methodology allows the preparation of future specialists for professional activities in the context of the digital transformation of science and education. The paper highlights the pedagogical value of the Wolfram Demonstrations Project as an accessible and interactive supplement to theoretical instruction and physical experimentation. The results confirm that incorporating Wolfram Mathematica into the laboratory framework supports the development of digital competencies, critical thinking, and a research-oriented mindset. Ultimately, the implementation of this methodology prepares students for professional scientific work in an era of digital transformation in science and education.

Keywords: *Newton's rings, Wolfram Mathematica, interference, experimental data processing, physics workshop, Wolfram Demonstrations Project, computer modeling, optics.*

In cites: *N. S. Shyshko, T. R. Zetova. Using wolfram mathematica to process the results of the laboratory work "Newton's ring".* Journal of V. N. Karazìn Kharkiv National University. Series Physics. Iss. 42, 2025, 74-78. https://doi.org/10.26565/2222-5617-20250-42-10

INTRODUCTION

The modern system of higher education is actively introducing advanced information technologies that significantly enrich the methodological arsenal of the teacher and expand the opportunities for students to acquire professional competencies [1]. This is especially important in the study of physics, where the experimental component plays a fundamental role in shaping the scientific outlook and practical skills of future professionals. A laboratory workshop in physics requires not only high-quality experiments, but also the correct processing of the results, their interpretation, and formulation of conclusions [2].

The Wolfram software environment, which includes Wolfram Mathematica and the Wolfram Demonstrations Project, is a powerful tool for implementing computational, analytical, and visualization tasks in physics. It allows you to automate routine calculations, improve their accuracy, and provide a clear presentation of data [3]. This is especially important in the study of wave optics and, in particular, interference phenomena, the visualization of which is often difficult using traditional methods.

The purpose of this article is to analyze the possibilities and features of using the Wolfram software environment for processing the results of laboratory work in physics on the example of an experiment on the study of Newton's rings. Attention is also paid to the methodological aspects of using Wolfram in the educational process and its integration into the laboratory workshop on physics in higher education institutions.

THEORETICAL FOUNDATIONS OF THE NEWTON RINGS PHENOMENON

Newton's rings are a classical interference phenomenon observed when light is reflected from two surfaces forming a thin air gap of variable thickness [4]. A typical experimental setup consists of a flat-convex lens with a large radius of curvature located on a flat glass plate. When such a system is illuminated with monochromatic light, a characteristic interference pattern in the form of concentric light and dark rings is observed.

The intensity of the reflected light at the point corresponding to the distance r from the center of contact between the lens and the plate is determined by the formula (1):

$$I(r) = I_0 \frac{4R_1R_2 sin^2(\delta/2)}{\left(1-\sqrt{R_1R_2}\right)^2}, \tag{1}$$

where I_0 - is the intensity of the incident light, R_1 and R_2 – are the reflection coefficients from the upper and lower surfaces, δ – is the phase difference between the rays, defined as (2):

$$\delta = \frac{4\pi}{\lambda} d(r). \tag{2}$$

The thickness of the air gap $d(r)$ at a distance r from the contact point for a spherical surface of radius R is defined as (3):

$$d(r) \approx \frac{r^2}{2R}. \tag{3}$$

For dark rings, the condition is satisfied:

$$d(r) = \frac{m\lambda}{2}, \tag{4}$$

where m – is an integer (interference order), λ – is the wavelength of light.

The radius of dark rings determined by the formula:

$$r_m = \sqrt{m\lambda R}. \tag{5}$$

Thus, measuring the radius of the rings allows you to determine the radius of curvature of the lens or the wavelength of light [4].

MODELING OF NEWTON RINGS IN WOLFRAM ENVIRONMENT

Wolfram Mathematica provides ample opportunities for modeling physical processes and phenomena thanks to its powerful mathematical apparatus and flexible visualization tools. Let's consider the main stages of modeling Newton's rings in this environment.

Stage 1: Defining input parameters

It is necessary to set the physical parameters of the system: the radius of curvature of the lens R, the wavelength of light λ, the reflection coefficients R_1 and R_2.

Stage 2: Defining the intensity function

Based on theoretical formulas, we create a function to calculate the intensity of the reflected light depending on the distance from the center.

Stage 3: Visualization of results

Several approaches can be used to visualize the interference pattern. The figures show the results of computer modeling of the classical optical phenomenon of Newton's rings observed in reflected monochromatic light. The modeling was performed using the following parameters: radius of curvature of a flat-convex lens R = 105 cm and wavelength of incident light λ = 650 nm.

1. A two-dimensional image of the interference pattern. Figure 1 visualizes the two-dimensional

interference pattern. It consists of a system of concentric rings, where the bright fringes correspond to interference maxima, and the dark fringes correspond to minima. A characteristic feature of the pattern in reflected light is the presence of a dark spot at the center ($r = 0$). This is due to the additional phase shift of π upon the reflection of the light wave from the boundary with an optically denser medium (the surface of the flat glass plate). It is observed that as the radius increases, the rings become narrower and the distance between them decreases.

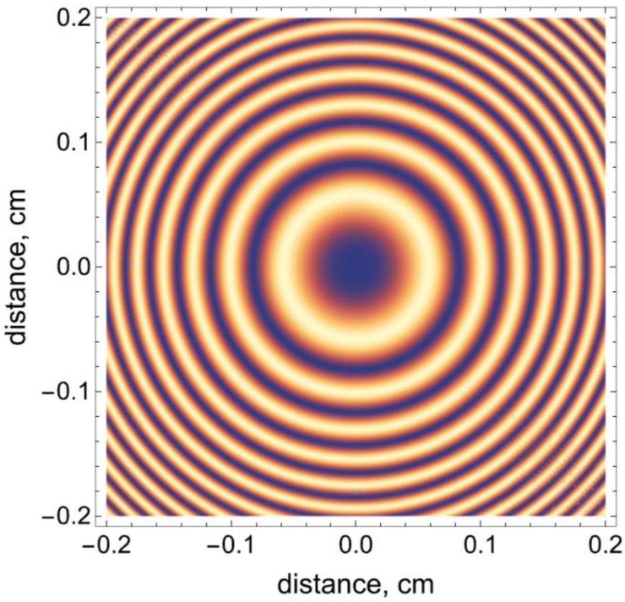

Fig. 1. The interference pattern of Newton's rings, depending on the back wavelength and radius of curvature of the lens.

2. One-dimensional graph of intensity versus distance. Figure 2 shows a quantitative plot of the light intensity I (in arbitrary units) versus the radius r (in cm). The dashed line represents the calculated intensity profile. The plot confirms that the intensity at the center of the system ($r = 0$) is zero. Subsequently, the intensity oscillates, reaching a normalized maximum value at the positions corresponding to the bright rings. With increasing radius, the frequency of these oscillations increases, which correlates with the densification of the rings observed in Figure 1. This plot allows for the precise determination of the radii of the bright and dark rings and the analysis of the change in their width.

For a more realistic display of Newton's rings, you can use the RevolutionPlot3D function, which creates a three-dimensional image based on the rotation of the function around the axis.

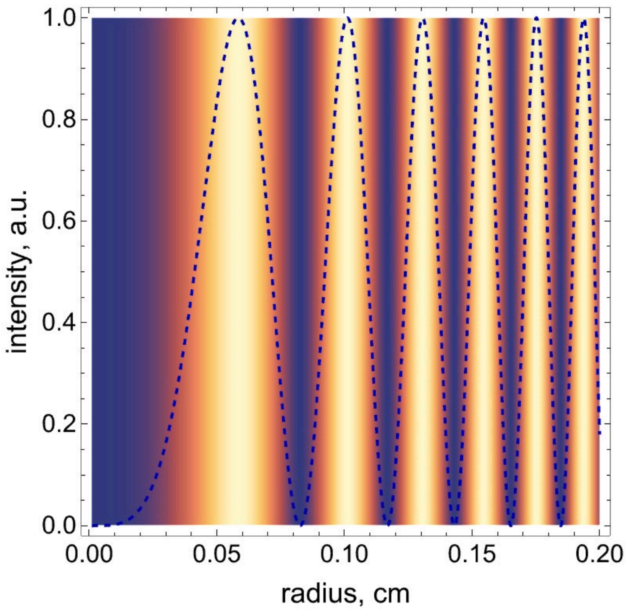

Fig. 2. Dependence of light intensity on the radius of Newton's rings.

Stage 4: Analyze experimental data

Wolfram Mathematica allows you to efficiently process experimental data for comparison with the theoretical model. Suppose we have a set of experimental values of dark ring radii r_m for different interference orders m:

To determine the radius of curvature of the lens, we can use the least-squares method. According to the theoretical formula, the square of the ring radius is directly proportional to the interference order.

USING WOLFRAM DEMONSTRATIONS PROJECT IN THE EDUCATIONAL PROCESS

The Wolfram Demonstrations Project is an open platform for interactive demonstrations created in the Wolfram Mathematica environment [5]. The project contains thousands of demonstrations from various fields of knowledge, including physics. Particularly noteworthy is the demonstration “Intensity Profiles for Newton's Rings” [6], which allows visualizing the interference pattern of Newton's rings and studying the dependence of its characteristics on various parameters.

This demonstration allows you to dynamically change these parameters:

- the radius of curvature of the lens;
- wavelength of light;
- refractive indices of media.

Using such interactive demonstrations in the learning process has a number of advantages:

1. **Visibility -** students can directly observe the effect of changing parameters on the interference pattern.
2. **Interactivity -** the ability to experiment with parameters in real time stimulates research activity.

3. **Accessibility -** to view the demonstrations, it is enough to have Wolfram Player, which is distributed free of charge [7].
4. **Integrated approach -** the combination of theory, experiment and computer modeling provides a deeper understanding of physical phenomena.

To effectively use the Wolfram Demonstrations Project in a laboratory workshop, we recommend the following approach:

1. Familiarizing students with the theoretical foundations of the phenomenon of Newton's rings.
2. Conducting a traditional experiment by measuring the radii of rings.
3. Processing the results using Wolfram Mathematica.
4. Comparison of experimental data with a theoretical model and a demonstration from the Wolfram Demonstrations Project.
5. Analysis of possible sources of errors and discussion of results.

GUIDELINES FOR IMPLEMENTING WOLFRAM IN THE LABORATORY WORKSHOP

Based on the study, we can formulate the following methodological recommendations for the implementation of the Wolfram software environment in a laboratory physics workshop:

1. **The preparatory stage** is the development of methodological materials that contain basic information about working in Wolfram Mathematica and describe the data processing algorithm for a particular experiment [8].
2. **Integration with traditional methods** - Wolfram should be considered as a complement to traditional methods of conducting and processing experimental results, not as a replacement.
3. **Gradual introduction -** start with simple tasks with gradual complication so that students can master the basic principles of working with the software environment.
4. **Individual approach -** tasks can be adapted to different levels of students' training, which contributes to the implementation of the principle of individualized learning.
5. **Interdisciplinary connections -** the use of Wolfram helps to strengthen interdisciplinary connections between physics, mathematics and computer science [9].

CONCLUSIONS

The use of the Wolfram software environment to process the results of physics laboratory work, in particular when studying Newton's rings, has significant didactic potential and opens up new opportunities to improve the efficiency of the educational process.

The main advantages of this approach are:

1. Improving the accuracy of experimental data processing through the use of powerful mathematical methods.
2. Improving the visualization of physical phenomena contributes to a deeper understanding of the essence of processes.
3. Development of students' skills in working with modern software tools that are widely used in scientific and engineering practice.
4. Stimulation of students' research activities through the opportunity to experiment with model parameters.
5. Saving time on routine calculations, allows you to focus on analyzing and interpreting the results.

The integration of Wolfram into the laboratory workshop should be carried out with due regard to didactic principles and with appropriate methodological support. This will ensure that students develop a holistic view of scientific research methods and prepare them for professional activities in the context of the digital transformation of science and education.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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ВИКОРИСТАННЯ ПРОГРАМНОГО СЕРЕДОВИЩА WOLFRAM MATHEMATICA ДЛЯ ОБРОБКИ РЕЗУЛЬТАТІВ ЛАБОРАТОРНОЇ РОБОТИ "КІЛЬЦЯ НЬЮТОНА"

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Надійшла до редакції 7 квітня 2025 р. Переглянуто 20 травня 2025 р.
Прийнято до друку 22 травня 2025 р.

У статті розглядається актуальна проблема впровадження сучасних інформаційних технологій у фізичний практикум, що підвищує ефективність навчального процесу та сприяє формуванню дослідницьких компетенцій студентів. Метою дослідження є аналіз можливостей програмного середовища Wolfram Mathematica для обробки та візуалізації результатів експериментів на прикладі лабораторної роботи "Кільця Ньютона". Методи дослідження вміщують теоретичний аналіз інтерференційних явищ, комп'ютерне моделювання у середовищі Wolfram Mathematica та використання інтерактивних демонстрацій Wolfram Demonstrations Project. Запропоновано оригінальний алгоритм обробки експериментальних даних, який дозволяє автоматизувати розрахунки та підвищити їх точність. Результати дослідження представлені у формі математичної моделі кілець Ньютона, що забезпечує наочну візуалізацію інтерференційної картини та дозволяє вивчати залежність її характеристик від різних фізичних параметрів системи (радіус кривизни лінзи, довжина хвилі). Розроблено детальні методичні рекомендації щодо інтеграції програмного середовища Wolfram Mathematica у структуру лабораторного практикуму з фізики. Доведено, що використання програмного забезпечення Wolfram Mathematica сприяє розвитку навичок роботи із сучасними програмними засобами, стимулює дослідницьку діяльність студентів та забезпечує міждисциплінарні зв'язки між фізикою, математикою та інформатикою. Впровадження запропонованої методики дозволяє підготувати майбутніх фахівців до професійної діяльності в умовах цифрової трансформації науки та освіти. Підкреслено педагогічну цінність інтерактивних демонстрацій Wolfram Demonstrations Project як доступного та ефективного інструменту для поглиблення розуміння матеріалу. Результати підтверджують, що включення системи Wolfram Mathematica у лабораторні роботи з фізики є потужним каталізатором для розвитку цифрових компетентностей, критичного мислення та дослідницького мислення студентів, що є основним висновком роботи.

Ключові слова: *кільця Ньютона, Wolfram Mathematica, інтерференція, обробка експериментальних даних, фізичний практикум, Wolfram Demonstrations Project, комп'ютерне моделювання, оптика.*