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ВІДОМОСТІ ПРО АВТОРІВ

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Коло наукових інтересів: теорія і методика навчання фізики і астрономії.

STUDYING OF LENSES AND THEIR PROPERTIES

Olena TRIFONOVA

В статі розглядається експериментальна методика навчання поширення світла у лінзах, призмах, плоских пластинках та у посудині з водою.

The article is devoted to experimental studying of light passing through lenses, prisms, plates in water.

Inform the students that a clear material, e.g. glass, which reflects or refracts light can, for particular curve shapes, cause parallel rays of light to converge at a point. Reflecting surfaces, curved or not, are referred to as mirrors in optics. Mirrors have one focal point to go with their one curved surface. A refracting material with two curved surfaces is called a lens. Since a lens has two curved surfaces, it has two focal points. If the curved surfaces are close enough together that we can neglect the distance between the surfaces, we refer to it as a thin lens.

It is known from the school course of physics that a lens can be one of two types:

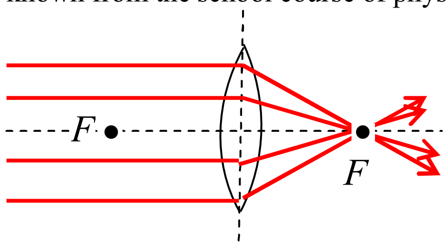


Figure 1

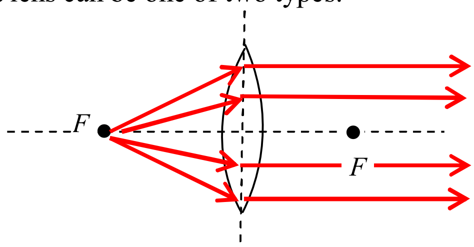


Figure 2

converging a lens in which parallel rays of light passing through the lens are brought together at the focal point. Rays of light which come from a point object placed at one of the focal points and which pass through the lens are converted into parallel rays (see figure 1).

First and second focal points of a converging thin lens.

- **diverging** a lens in which parallel rays of light diverge after passing through the lens. The focal length of a diverging lens is defined as a *negative* quantity, see figure 3).

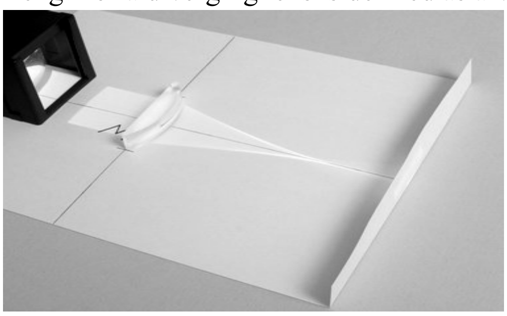


Figure 3

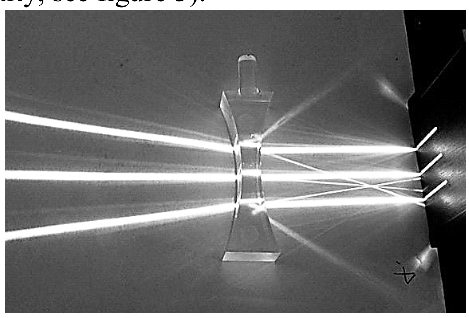


Figure 4

Experiment 1. Construction focal points.

Equipment: source of light, lens, horizontal screen.

First and second focal points of a diverging thin lens and the negative focal length.

Direct a parallel beam of light to a lens, figure 3. Construction of a focal points on the horizontal screen. Drawing motion ray, figure 1, 2.

Experiment 2. Studying ray in concave lens.

Equipment: source of light, concave lens, horizontal screen.

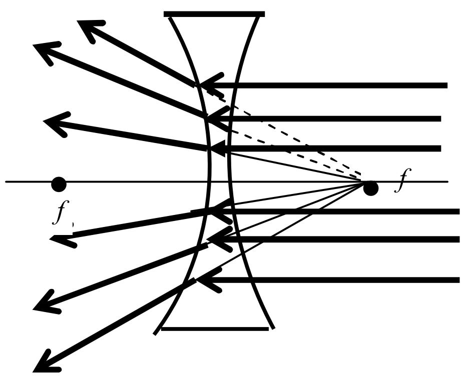


Figure 5

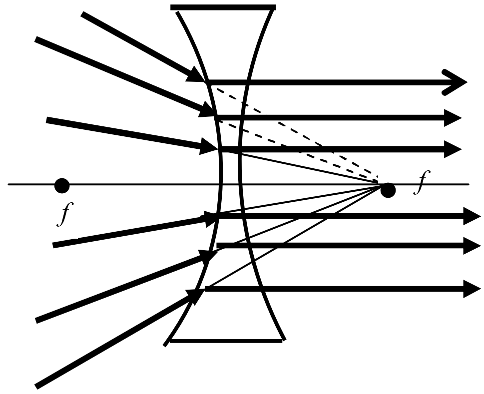


Figure 6

Direct parallel rays from spring light to a concave lens, figure 4. We offer to practice in drawing of rays motion, figure 5, 6.

Studying of lens.

We can use a lens to image an object. In the case of a thin lens, we define the **object distance**, *d*, as the distance of the object from the centre of the thin lens. The **image distance**, *f*, is the distance of the image formed from the centre of the thin lens, and we usually term the **focal distance**, *f*, as the distance of the focal point from the centre of the thin lens, see figure 7.

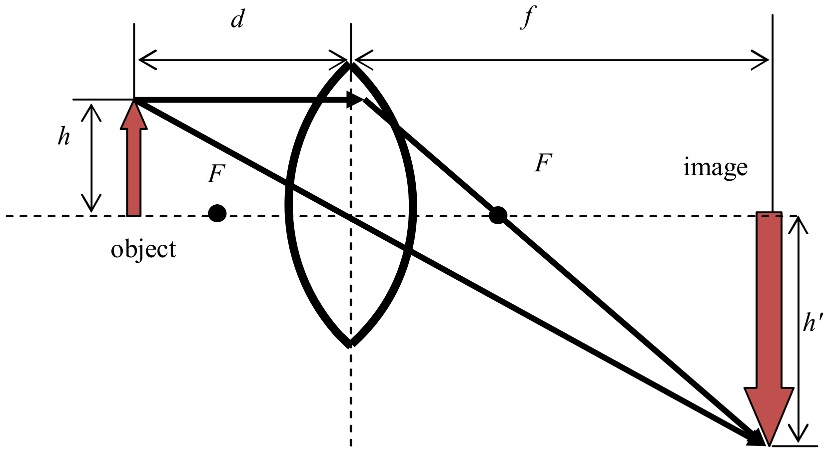


Figure 7. Definition of image, object, and focal lengths for a thin lens

The object, image, and focal lengths are related by the formula $\frac{1}{d}+\frac{1}{f}=\frac{1}{F}$.

Furthermore, the size of the image in the plane of the image, object, and lens, which we depict as *h*, is related to the size of the object (call it *y*) by the **magnification**. The magnification is $m=\frac{h'}{h}=\frac{f}{d}$.

We define images which are on the same side of a converging lens as the object as *virtual*. Note that in such cases $d<0$ and the magnification is *positive*. For *real* images, the image is inverted compared to the object h' have opposite signs. Hence a positive magnification corresponds to an erect, virtual image while a negative magnification corresponds to an inverted, real image.

Let's consider an example.

Problem 1:

We have tools: lens with a focal length of 7,00 cm on the table.

A converging lens with a focal length of 7,00 cm forms a 1,30 cm tall image of a 4,00 mm tall real object that is to the left of the lens. The image is erect. Find the locations of the object and the image and determine whether the image is real or virtual.

Solution:

Since we have the sizes of the images, we can find the magnification.

$$m = \frac{h'}{h} = \frac{13}{4} = +3{,}25 .$$

Notice that since the image is erect, $h > 0$ and the image is virtual. The magnification also implies $m = \frac{f}{d}$ and $f = 3{,}25d$.

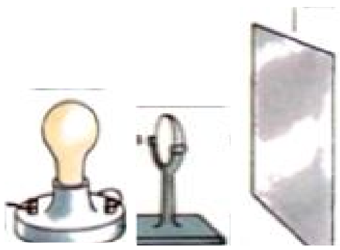
Since s is positive (the object is real), the image distance is negative so it is located to the left of the lens as the object is. We now find the distances for the object and the image.

So the image is located 15,8 cm to the left of the lens and the object is located 4,85 cm to the left of the lens.

Experiment 3. Laboratory investigation [1, p. 406] Images Produced by a Convex Lens.

Problem. How is the image formed by a convex lens dependent on the distance between the lens and the object?

In this investigation, the students will learn how real and virtual images are produced by a thin co convex lens, figure 8.



Focal length

Light souce Convex lens Screen

Figure 8

Each group of students will need a convex lens, lens holder, screen, meter stick, support stands, and a light source, such as a light bulb.

Procedure.

1. Arrange the apparatus as shown in the illustration. Place the light source at least 2 m away from the lens. Then make a table like the one shown below.

2. Focus the light rays of the source of light on the screen. The image should be bright and clear. For practical purposes, the light rays from such a distant source come in parallel to the principal axis of the lens. Describe and measure the size of the image and of the light source, which serves as the object. Measure and record the focal length, which is the distance between the lens and the focused rays on the screen.

3. Move the light source to a position that is greater than twice the focal length of the lens.

Object distance	Object size	Image position (erect or inverted)	Image size	Focal length

Align the lens, the source, and the screen so that the image falls in sharp focus on the screen. Record the image size and the distance of the object and screen from the lens in the table. Record the size of the object.

4. Move the light source to a point that is exactly twice the focal length. Adjust the lens and screen to obtain a sharp image. Record the information required in the data table.

5. Try moving the light source to other distances from the lens. What happens to the image size and distance?

Experiment 4. Studying of light refraction in a prism.

Equipment: source light, prism, screen.

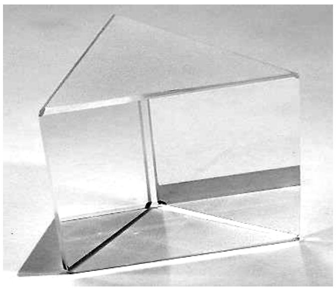


Figure 10

In optics, a prism is a transparent optical element with flat, polished surfaces that refract light figure 10. The exact angles between the surfaces depend on the application. The traditional geometrical shape is that of a triangular prism with a triangular base and rectangular sides, and in colloquial use “prism” usually refers to this type. Some types of optical prism are not in fact in the shape of geometric prisms. Prisms can be made from any material that is transparent to the wavelengths for which they are designed. Typical materials include glass, plastic and fluorite.

Experiment 5. Studying of light refraction in a lens.

Equipment: source of light, lens, screen.

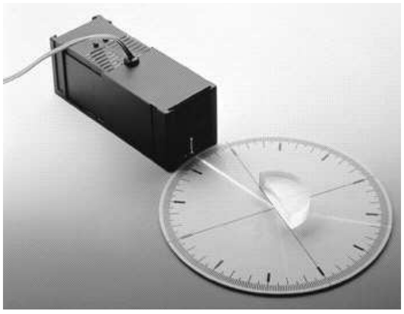


Figure 11

Principle. In conjunction with the experiments on the refraction of light, this experiment is of particular importance, figure 11. Knowledge of the law of refraction is strengthened and transferred to new contexts. At the same time, in this experiment, the students become familiar with the lenses which are most frequently used in optical apparatus.

The main focus of the first part of the experiment concerns the observation of the course of parallel, incident light beams converged by a convex lens and strengthening the concept of focal length.

In the second part of the experiment, the path of three selected light beams is experimentally investigated and the general prerequisites for the understanding of image formation, to reconsidered later, are laid down [3].

The second part of the experiment is more demanding in terms of the abilities and experimental skills required of the students. Both experiments can be seen as individual units and can, likewise, be carried out separately. This is to be recommended in the interest of conscientious performance and further strengthening of the students experimental skills.

Nevertheless, individual group work can also be recommended (each group investigating the course of different, selected light beams then, at the end of the experiment, the data is collected to give a total result).

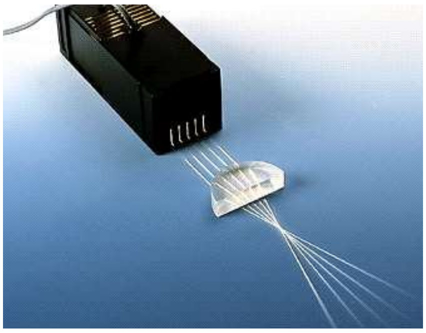


Figure 12

Task.

1. How does light pass through a lens?
2. Investigate the passage of light through a plane convex lens.
3. Investigate the passage of selected light rays falling on a plane convex lens.

Principle. In this experiment, the students have the possibility of perfecting their experimental skills and strengthening their understanding of the law of refraction, figure 12. In conjunction with the observation of incident light at the boundary between air and glass, the path of the light beam is determined and evaluated by using a semigraphical procedure. In this way, the importance of mathematics for the understanding of physics can be demonstrated [4].

The experiment is demanding in terms of the experimental skills of the students. Only after careful adjustments and a conscientious evaluation can good results be obtained.

Studying the move of the rays in parallel plate.

Approach. We apply Snell's law at the first surface, where the light enters the glass, and again at the second surface where it leaves the glass and enters the air.

Solution (a). The incident ray is in air, so $n_1 = 1{,}00$ and $n_2 = 1{,}50$. Applying Snell's law where the light enters the glass $\alpha = 60$. It gives $\beta = 35{,}3$.

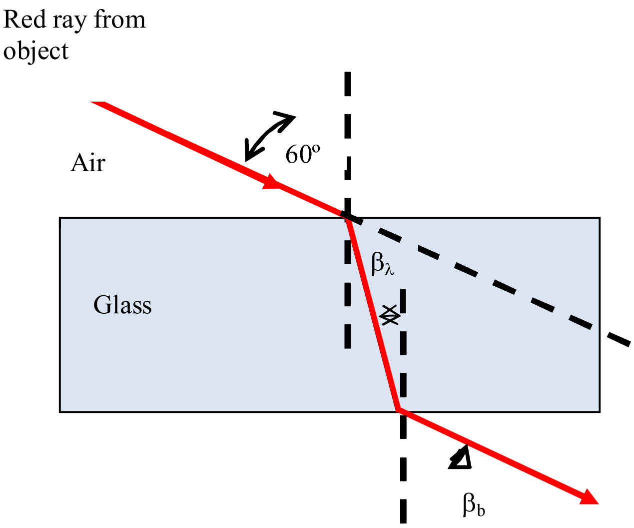


Figure 13. Image when viewed through the glass

Since the faces of the glass are parallel, the incident angle at the second surface is just β (simple geometry), so $\sin\beta = 0{,}5774$. At this second interface, $n_1 = 1{,}50$ and $n_2 = 1{,}00$. The direction of a light ray is thus unchanged by passing through a flat piece of glass of uniform thickness [2, p. 851].

Experiment 6. Determination of apparent depth of a pool.

A swimmer has dropped her ring to the bottom of a pool at the shallow end, marked as $1{,}00m$ deep. But the ring doesn't look that deep. Why? How deep do the ring appears to be when you look straight down into the water?

Approach We draw a ray diagram showing two rays going upward from a point on the ring at a small angle, and being refracted at the water's (flat) surface, figure 14. The two rays traveling upward from the ring are refracted away from the normal as they exit the water, and so appear to be diverging from a point above the ring (dashed lines), which is why the water seems less deep than it actually is.

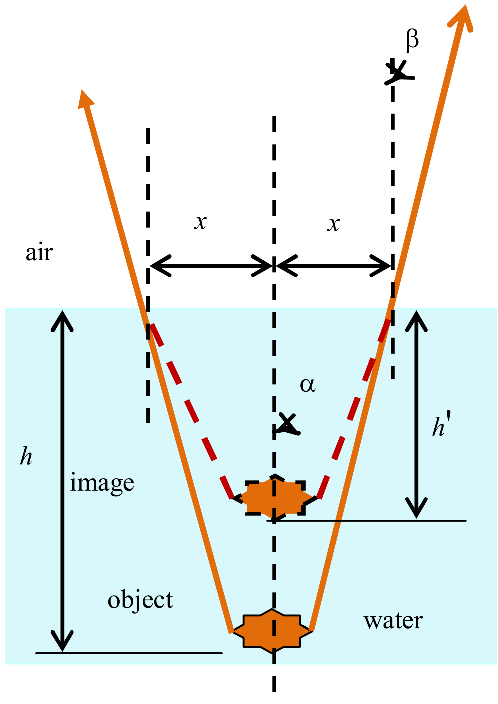


Figure 14

Solution. To calculate the apparent depth h' (figure 14), given a real depth $h = 1{,}0 \cdot m$, we use Snell's law with $n_1 = 1{,}33$ for water and $n_2 = 1{,}0$ for air: $\sin\alpha = \sin\beta$.

We are considering only small angles, so $\sin\alpha \sim \operatorname{tg}\alpha$ with 9 in radians. So Snell's law becomes $\beta \approx n_1\alpha$. From figure 14, we see that $\beta \approx \operatorname{tg}\beta = \frac{x}{h'}$ and $\alpha \approx \operatorname{tg}\alpha = \frac{x}{d}$.

Putting these into Snell's law we get $\frac{x}{h'} \approx \frac{n_1 x}{h}$ and

$$h' \approx \frac{h}{n_1} = \frac{1{,}0m}{1{,}33} = 0{,}75m.$$

The pool seems only three-fourths as deep as it actually is.

Experiment 7. Study of notion «Optical illusion» (mirage).

Fermat's principle states that the ray path from an observer at *A* to a point *B* in space is an extremal of optical length figure 15. For example, along a sunbaked road, the temperature of the air is warmest near the road and decreases with height, so that the index of refraction, n, increases in the vertical direction.

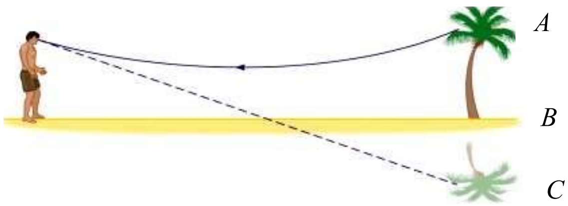


Figure 15

For an observer at *A*, the curved path has a smaller optical path than the straight line. Therefore, he sees not only the direct line-of-sight image of the tree top at *B*, but it also appears to him that the tree top has a mirror image at *C*. If there is no tree, the observer sees a direct image of the sky and also its mirror image, thereby giving the impression, perhaps sadly, that he is looking at water [5].

Conclusion. Offered experimental methods of studying the light passing through the lens help to form student's virtual thinking and qualified mastering of optic phenomena. They individually change directions between the objects and lenses, prisms, and flat, parallel plates.

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МОДЕЛЮВАННЯ ФІЗИЧНОЇ СИТУАЦІЇ ПРИ ФОРМУВАННІ ПРАКТИЧНОЇ КОМПЕТЕНТНОСТІ УЧНІВ З РОЗВ'ЯЗУВАННЯ ФІЗИЧНИХ ЗАДАЧ

Катерина ЧОРНОБАЙ

У статті розглянуто проблему формування практичної компетентності школярів з питань розв'язування задач. Наведено приклади розв'язування задач, в яких акцентується увага на моделюванні фізичної ситуації як однієї з основоположних процесу розв'язування будь-якого типу задач з фізики.

The article considers the problem of forming practical competence of students on the issues of solving the tasks. It contains examples of solutions of the tasks in which the attention is paid on the modeling of physical situation as a fundamental process of solving any kind of tasks in physics.

Одним із сучасних напрямків реформування освіти в Україні, згідно з Державним стандартом базової і повної середньої освіти [1] є впровадження компетентністного підходу, згідно якого головною метою фізичної освіти є формування та розвиток соціально-особистісної, комунікативної, інформаційної, практичної та загальнокультурної компетентностей.

Науковими дослідженнями з питань впровадження компетентнісної освіти у навчальний процес як у вищій, так і у середній школі займались І. Бех, Ю. Галатюк, С. Гончаренко,