

## CALCULATING THE ANGLE OF DEVIATION OF LIGHT FOR A TRIANGULAR PRISM

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### **Abstract**

This paper focuses on the analysis of a triangular prism, in which the dependence of the angle between the incident and emerging rays on the prism's refracting angle is derived. The study considers the general scenario where the prism is embedded between two distinct optical media.

### **Keywords**

Triangular prism, prism refracting angle, Snell's law, angle of deviation, light ray.

### **Annotatsiya**

Ushbu maqola uchburchakli prizmaga bag'ishlangan bo'lib, unda prizmaga tushuvchi undan chiquvchi nurlar orasidagi burchakning prizmaning sindirish burchagiga bog'liqligi keltirib chiqarilgan. Bunda umumiy hol korilgan, ya'ni prizma ikki xil muhitda joylashgan hol.

### **Kalit so'zlar**

Uchburchakli prizma, prizmaning sindirish burchagi, Snellius qonuni, og'ish burchagi, yorug'lik nuri.

The refraction of light in a prism is an important characteristic of optical phenomena, encompassing the study of the laws governing the behavior of light waves as they pass from one medium to another. This article provides a scientific analysis of the process of light refraction through a prism, including key physical concepts such as Snell's law, the angle of refraction in a prism, and dispersion. In

addition, the practical significance of light refraction in prisms and its applications in optical technologies are also discussed.

The change in the direction of light as it passes from one medium to another is known as refraction. This phenomenon is explained by the difference in the speed of light in different media. To mathematically describe the process of light refraction, **Snell's law** is applied, which can be expressed as follows:

$$\frac{\sin \alpha}{\sin \gamma} = \frac{n_2}{n_1}$$

A **prism** is an optical device characterized by two inclined surfaces, typically made of transparent materials such as glass or plastic. The refraction of light within a prism depends on several parameters, including the prism's refracting angle, the refractive indices of the media, and the angle of incidence of the incoming light.

As a result of light refraction in a prism, the phenomenon of dispersion occurs, whereby white light is separated into its constituent spectral colors. This is due to the fact that each spectral component of light (such as red, blue, and green) has a different refractive index. Red light undergoes less refraction, while blue light is refracted more strongly, leading to the spatial separation of colors.

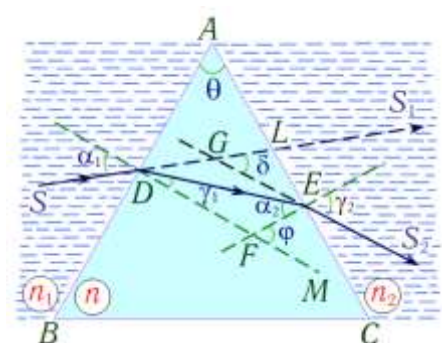
The phenomena of refraction and dispersion of light in a prism have numerous practical applications. For example:

1. **Spectroscopy:** In physics and chemistry, spectral analysis is used to determine the composition of substances.
2. **Optical instruments:** Prisms are essential components in devices such as microscopes, telescopes, and other optical systems.
3. **Color separation:** Prisms are used in optical filters to separate different spectral ranges of light.

Through laboratory experiments, the phenomena of refraction and dispersion of light in a prism can be observed in practice. A simple experiment clearly demonstrates the separation of white light into a visible color spectrum when passing through a prism. Experimental results confirm Snell's law and the theory of dispersion.

The refraction of light in a prism is an essential part of optics, encompassing the processes of light transmission between media, changes in propagation angles, and dispersion. A thorough understanding of these processes plays a significant role in the development of optical technologies and provides broad opportunities for further scientific research.

Consider a prism with a refracting angle  $\theta$ . Let a light ray  $S$  be incident on face  $AB$  of the prism at an



angle  $\alpha_1$ . After undergoing two refractions within the prism, the ray emerges from face  $AC$  in the direction  $S_2$  at an angle  $\gamma_2$ . As a result, the emergent ray deviates from its original direction by an angle  $\delta$ , which is referred to as the *angle of deviation*. If the angle of incidence  $\alpha_1$  is small, then the refracting angle  $\theta$  is also small, and such a prism is referred to as a *thin prism*. For this type of prism, let us derive the relationship between the angle of deviation  $\delta$  and the prism's refracting angle  $\theta$ . The prism is immersed in two liquids with refractive indices  $n_1$  and  $n_2$  in such a way that the liquid with refractive index  $n_1$  is adjacent to face  $AB$ , while the liquid with refractive index  $n_2$  is adjacent to face  $AC$ . The incident ray  $S$  lies in the plane of the triangular prism  $ABC$ .

Let us describe the following elements based on the figure:

$$\begin{aligned} \angle LGE &= \delta, \quad \angle EFM = \varphi, \quad \angle DGF = \alpha_1, \quad \angle GEF = \gamma_2, \\ \angle ADF &= 90^\circ, \quad \angle LEF = 90^\circ, \quad \angle GDE = \alpha_1 - \gamma_1, \quad \angle GED = \gamma_2 - \alpha_2. \end{aligned}$$

Since the desired angle of deviation  $\delta$  is the exterior angle of triangle  $GDE$ , it is equal to the sum of the non-adjacent interior angles, that is:

$$\delta = (\alpha_1 - \gamma_1) + (\gamma_2 - \alpha_2), \tag{1}$$

here,  $\alpha_1$  and  $\gamma_1$  denote the angles of incidence and refraction at face  $AB$ , while  $\alpha_2$  and  $\gamma_2$  denote the angles of incidence and refraction at face  $AC$ .

Given the refracting angle  $\theta$  and the refractive indices  $n_1$ ,  $n_2$  and  $n$ , the angle of deviation  $\delta$  should be expressed in terms of these parameters. In this case, the refractive indices of the liquids are assumed to be smaller than that of the prism, i.e.,  $n_1, n_2 < n$ . For the rays incident on face  $AB$  and refracted through it, **Snell's law** can be written as follows:

$$\frac{\sin \alpha_1}{\sin \gamma_1} = \frac{n}{n_1}. \tag{2}$$

The ray of light  $S$ , refracted at face  $AB$ , strikes face  $AC$  at an angle  $\alpha_2$ . To prevent total internal reflection at face  $AC$ , the condition  $\sin \alpha_2 < \frac{n_2}{n}$  must be satisfied. If this condition holds, the light ray emerges from the prism into the medium with refractive index  $n_2$  at an angle  $\gamma_2$ . For the rays incident on face  $AC$  and refracted through it, **Snell's law** can be written as follows:

$$\frac{\sin \alpha_2}{\sin \gamma_2} = \frac{n_2}{n}. \tag{3}$$

If the angle of incidence  $\alpha_1$  at face  $AB$  and the prism's refracting angle are small, then the angles  $\gamma_1$ ,  $\alpha_2$  and  $\gamma_2$  are also small. In this case, equations (2) and (3) can be expressed as follows:

$$\alpha_1 \approx \frac{n}{n_1} \gamma_1, \quad \gamma_2 \approx \frac{n}{n_2} \alpha_2. \quad (4)$$

Considering that the exterior angle  $\varphi$  of triangle  $DFE$  is equal to the sum of its non-adjacent interior angles, we can express the following relationship

$$\varphi = \gamma_1 + \alpha_2. \quad (5)$$

Similarly, the sum of the interior angles of quadrilateral  $ADFE$  is equal to  $\theta + 90^\circ + 180 - \varphi + 90^\circ = 360^\circ$ .

After simplification we obtain the following:

$$\theta = \varphi. \quad (7)$$

Substituting equation (4) into equation (1) we obtain the following expression

$$\delta = \left(\frac{n}{n_1} \gamma_1 - \gamma_1\right) + \left(\frac{n}{n_2} \alpha_2 - \alpha_2\right). \quad (8)$$

From this the following expression is obtained

$$\delta = n \left(\frac{1}{n_1} \gamma_1 + \frac{1}{n_2} \alpha_2\right) - (\gamma_1 + \alpha_2) \quad (9)$$

If the refractive indices of the first and second media are equal, that is  $n_1 = n_2$ , then equation (9) can be written as follows

$$\delta = \frac{n}{n_1} (\gamma_1 + \alpha_2) - (\gamma_1 + \alpha_2) = \left(\frac{n}{n_1} - 1\right) (\gamma_1 + \alpha_2). \quad (10)$$

Substituting equation (5) into equation (7), and then inserting the resulting expression into equation (10), we obtain the following expression

$$\delta = \left(\frac{n}{n_1} - 1\right) \theta. \quad (11)$$

Equation (11) represents the formula for a triangular prism.

## CONCLUSION

Right-angled isosceles triangular glass prisms are commonly employed in optical instruments such as periscopes and binoculars, enabling the redirection of light rays by  $90^\circ$  or  $180^\circ$ , as well as the inversion of images within optical systems. Consequently, the derived formula holds considerable practical and theoretical significance.

The present study examines a triangular prism immersed in two distinct media. The derived expressions can be applied in the analysis of lenses, in preparing school students for physics competitions, and in higher education for the study of the optics section of physics. Moreover, these results provide a valuable reference for educators and learners in specialized training centers.

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