Pre-lab Quiz/PHYS 224

Dispersion and Prism

Your name______________________ **Lab section_________________________**

1. What do we investigate in this lab?

2. Describe Snell's Law and draw a diagram.

3. As shown in Figure 4, the specific angle of the prism is $\alpha=60^o$. If the minimum angle of deviation of the ray after two refractions by the prism is measured as 24^o, find the refractive index, n, of the prism.

Lab Report/PHYS 224

Dispersion and Prism

Name_________________________________ **Lab section__________________________**

Objective

In this lab, you will use a prism spectrometer to investigate reflection and diffraction of light by prism, determine the refractive index of prism and the dispersion of light by measuring diffraction by prism.

Background

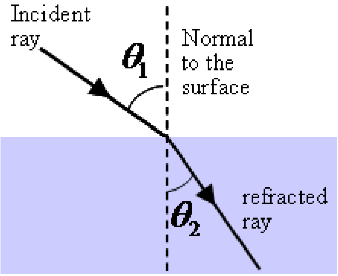

Figure 1

In geometric optics, propagation of light in a homogeneous media is described by using rays of light travelling in straight-line path. When light travels from medium 1 into medium 2, a ray of light changes the direction at the boundary between the two media. As shown in Figure 1, the change of direction obeys Snell's Law at a flat boundary:

$$n_1 \sin\theta_1 = n_1 \sin\theta_2 , \qquad (1)$$

where n_1 and n_2 are respectively the indices of refraction of medium 1 and medium 2, θ_1 is the angle of incidence, and θ_2 is the angle of refraction. It is of note that the index of refraction of a medium is the speed of light in the free space divided by the speed of light in the medium.

In the free space, the index of refraction is $n=1$, and is thus independent of wavelength. The index of refraction is approximately *1* in air. In other media, *n* depends on wavelength. Such a dispersive relationship is approximately described by Cauchy's equation with two constants C_1 and C_2:

$$n = C_1 + \frac{C_2}{\lambda_0^2} , \qquad (2)$$

where λ_0 is the wavelength of light in the free space. Following Snell's Law, *n* can be determined by measuring the deviation of the refracted ray from the incident ray. This method allows one to study the optical dispersion of materials using known light sources or to determine the optical spectrum using media of known dispersion.

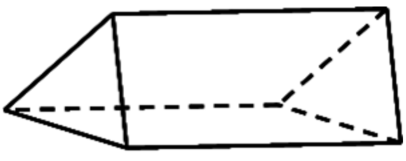
Figure 2

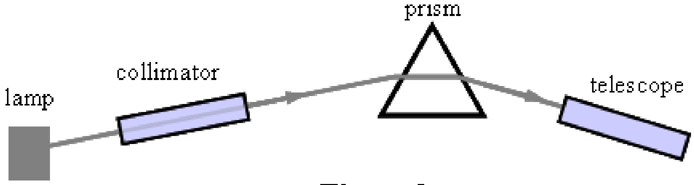

Figure 3

Prism spectrometers use transparent prisms to measure refraction of light. A prism (**Figure 2**) has three rectangular faces which are perpendicular to two triangular faces. **Figure 3** is a schematic view of the prism spectrometer used in this lab. The lamp heats up specific gas which emits light of specific wavelengths. The portion of light passing through the slits in the collimator forms a narrow beam of light travels in the direction aligned with the collimator. In **Figure 3**, one of the triangular faces of the prism is shown. Each of the three edges of the triangle represents one rectangular face.

In this lab, as shown in Figure 4, a beam of light (parallel with the triangular faces) shines on a rectangular face (represented by the left edge of the triangular face) with the angle of incidence as θ_1. After the first refraction at the left boundary, the ray travels in the prism and reaches another rectangular face (represented by the right edge of the triangular face). After the second refraction at the right boundary with the angle of refraction as θ_1, the ray travels again in air. The angle of deviation, σ, for the ray after the two refractions depends on θ_1, α (the angle between the two rectangular faces, namely, the angle between the left edge and the right edge as shown in Figure 3), and n (the index of refraction of the prism). Using Snell's Law and by the method of calculus, one can derive that σ reaches the minimum value, σ_{min}, at a special value of θ_1 which satisfies the condition $\theta_1=\theta_4$. Specifically, n is related to σ_{min} as follows

$$n = \sin(\tfrac{\alpha+\sigma_{\min}}{2}) / \sin(\tfrac{\alpha}{2})\,. \qquad (3)$$

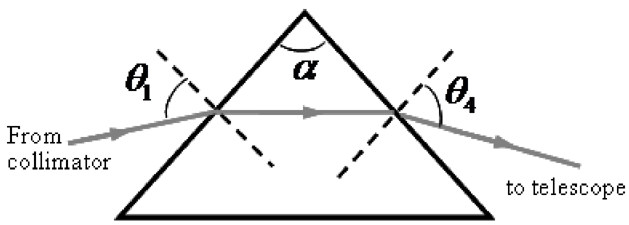

Figure 4

EXPERIMENT

Procedures

1. Align the telescope with collimator

Turn on the sodium-vapor lamp, which emits light of wavelength λ=589.3 nm (yellow). Use this light source to align the collimator and the telescope of the spectrometer. Rotate the telescope until you can see the yellow light (a vertical line) through the eyepiece. Now, adjust the eyepiece to make the image (including the horizontal and vertical axes) as sharp as possible. Then, slightly rotate the telescope until you see that the yellow light line coincides with the vertical axis. You may need to adjust the size of the slit on the collimator to achieve desired thickness for the light line.

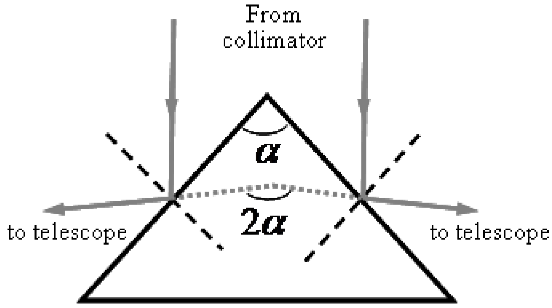

Figure 5

Now, the telescope and the collimator are aligned in a straight line. At such a condition, rays of light travel through the entire spectrometer in a straight-line path without deviation. Read the angular position of the telescope using the scale on the base. Record the angle θ_0 in Table 1.

2. Measure angle *α*

Place the glass prism at the center of the round platform between the collimator and the telescope, <u>with one triangular face at the bottom and the other at the top</u>. Arrange the prism to make one of its edges (the three edges should be the same) face the collimator (**Figure 5**), and such that light can be reflected from both the left and right rectangular faces of the prism.

Now, gradually rotate the telescope to the left to measure the reflected beam from the left rectangular face. When you see (through the eyepiece) that the image of a yellow light line coincides with the vertical axis, this is the direction of the reflected ray from the left rectangular face. Record the angle of the telescope θ_L in Table 1. (Note: to make sure that the image you see is from the reflected rays (not from the refracted rays), you may cover the left rectangular face of the prism; if the image disappears, then the image is indeed from the reflected rays; if not, search again.)

Similarly, gradually rotate the telescope to the right to determine the direction of the reflected rays by the right rectangular face. Record the corresponding angle of the telescope θ_R in Table 1.

Use $2\alpha = \theta_R - \theta_L$ to determine α.

TABLE 1

θ_0 **(º)**	θ_L **(º)**	θ_R **(º)**	α **(º)**

3. Measure the minimum angle of deviation (σ_{min}) for light of λ=589.3 nm

Rearrange the prism to make its left rectangular face the collimator and make the angle of incidence, θ_1, almost 45º (**Figure 4**). Then, gradually rotate the telescope to search for the image formed by the refraction, until you see that the image of the yellow light line coincides with the vertical axis. Now, slightly rotate the platform (on which the prism is placed) to the right to reduce θ_1. If you see on the eyepiece that the image of the yellow light line moves to the right, it means that σ is becoming smaller; keep rotating the platform slowly to the right to reduce θ_1. If the image of the yellow light line moves to the left, it means that σ is becoming larger; rotate the platform to the left to reduce θ_1. During this process, if the image of the yellow light line falls out of the field-of-view of the telescope, rotate the telescope to recapture the image. (Note: the above discussion is based on the setup depicted in Figure 3.)

When you reach $\boldsymbol{\sigma_{min}}$, rotating the platform to the right or to the left should both shift the image of the yellow light on the screen to the left. Read the angular position θ of the telescope on the base and record it in Table 2 for the yellow light of $\lambda=589.3$ nm.

Calculate the corresponding $\boldsymbol{\sigma_{min}} = /\theta - \theta_0/$ and record the $\boldsymbol{\sigma_{min}}$ value in Table 2.

4. Measure the minimum angle of deviation (σ_{min}) for light rays with $\lambda=578.2$ nm, *546.1* nm, and *435.8* nm

Turn off the sodium-vapor lamp and replace it by the mercury-vapor lamp. Turn on the mercury-vapor lamp, which emits light of λ=578.2 nm (yellow-orange), λ=546.1 nm (green), and λ=435.8 nm (blue).

Repeat procedure 3 for the yellow-orange light, measure $\boldsymbol{\sigma_{min}}$ for $\lambda=578.2$ nm. Read the corresponding angular position θ of the telescope on the base and record it in Table 2. Calculate the corresponding $\boldsymbol{\sigma_{min}} = /\theta - \theta_0/$ and record the $\boldsymbol{\sigma_{min}}$ value in Table 2.

Repeat procedure 3 for the green light, measure $\boldsymbol{\sigma_{min}}$ for $\lambda=546.1$ nm. Read the corresponding angular position θ of the telescope on the base and record it in Table 2. Calculate the corresponding $\boldsymbol{\sigma_{min}} = /\theta - \theta_0/$ and record the $\boldsymbol{\sigma_{min}}$ value in Table 2.

Repeat procedure 3 for the blue light, measure $\boldsymbol{\sigma_{min}}$ for $\lambda=435.8$ nm. Read the corresponding angular position θ of the telescope on the base and record it in Table 2. Calculate the corresponding $\boldsymbol{\sigma_{min}} = /\theta - \theta_0/$ and record the $\boldsymbol{\sigma_{min}}$ value in Table 2.

TABLE 2

λ (nm)	**θ (º)**	**minimum angle of deviation σ_{min}**	**refractive index *n***	**speed of light in glass *v***
589.3				
578.2				
546.1				
435.8				

Analysis

1. Calculate the refractive indices

Use Equation (3) and the measured σ_{min} values to calculate the refractive indices for the four wavelengths and record them in Table 1.

2. Fit for Cauchy's coefficients

Plot n versus $1/\lambda^2$ and fit by the linear relation described in Equation (2). Record the C_1 and C_2 values from the best fit (the correct units of both values must be specified):

C_1 =

C_2 =

Questions

1. Calculate the speed of light in glass for the four wavelengths and record in Table 1. For which wavelength light travels at the slowest speed? For which wavelength light travels at the fastest speed?

2. What is the maximum angle of deviation can be measured in this experiment as set up shown in Figure 4? Limited by this, what is the maximum value of refractive index which can be measured in this lab? (Hint: expressed both by using α.)