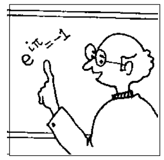

In this section of *Resonance*, we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. “Classroom” is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.

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Significance of the Minimum Deviation Position of a Prism

Here I present an explanation to the appearance of the spectrum obtained from a prism, as the prism is rotated towards or away from the minimum deviation position. I also propose a method to determine the refractive index of a prism not only in minimum deviation position but in any position. On discussion the importance of the minimum deviation position, a point generally not discussed in textbooks or in classrooms is also mentioned.

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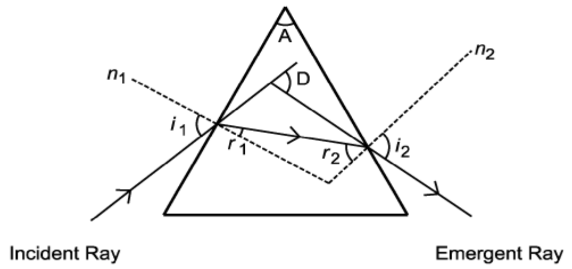
An Explanation to the Response of the Spectrum to the Rotation of Prism

Figure 1 shows the ray diagram of light passing through a prism, from which it follows

$$D = i_1 + i_2 - A \qquad (1)$$
$$A = r_1 + r_2 \qquad (2)$$
$$\mu = (1/\sin C) \qquad (3)$$

Keywords
Rotation of prism, incident light, angle of minimum deviation, refractive index.

Angle of deviation is the angle between the direction of incident and the emergent ray. It is observed that as the angle of incidence is changed, i.e., as the prism is rotated, the spectrum moves along



i_1 – angle of incidence; i_2 – angle of emergence; A – refracting angle of prism; D – angle of deviation; r_1 – angle of refraction at the first refracting face of the prism; r_2 – angle of incidence at the second refracting face of the prism; n_1, n_2 – normals.

Figure 1. Ray diagram of a prism.

with the prism but at minimum deviation, it appears to come to a halt and if the prism is further rotated in the same direction, then the spectrum retraces its path.

By assuming the incident light to be monochromatic, the value of the refractive index (μ) for the corresponding wavelength to be 1.5 and the refracting angle of the prism to be 60^o, the angle of minimum deviation D_m and the critical angle C are calculated using equations (1), (2), and (3), $D_m = 37.18°$ and $C = 41.81°$. The values of angle of emergence i_2 and the angle of deviation D, for various angles of incidence i_1 are calculated as shown in *Table* 1.

The change in angle of emergence (Δi_2) and the corresponding deviation in the angle of deviation (ΔD), with respect to the angle of incidence (i_1) are calculated with the help of *Table* 1 as shown in *Table* 2.

Angle of incidence(i_1) (in degrees)	Angle of emergence(i_2) (in degrees)	Angle of deviation (D) (in degrees)
30	77.095	47.095
35	65.990	40.997
40	58.465	38.466
45	52.381	37.381
48.59	**48.590**	**37.180**
50	47.209	37.209
55	42.738	37.738
60	38.870	38.870
65	35.588	40.588
70	32.867	42.867
75	30.723	45.723

Table 1. Values of i_2 and D for different values of i_1

Table 2. Change in i_2 and D with increase in i_1.

*The sudden increase in Δi_2 is due to the decrease in the length of the interval in the previous two entries. But if equal intervals are considered Δi_2 is found to decrease constantly.

Angle of incidence (i_1, in degrees)	Δi_2 (in degrees)	ΔD (in degrees)
30-35	11.105	6.092
35-40	7.525	2.531
40-45	6.084	1.084
45-48.59	**3.791**	**0.201**
48.59-50	**1.318**	**0.029**
50-55	4.471*	0.529
55-60	3.868	1.132
60-65	3.282	1.172
65-70	2.721	2.279
70-75	2.144	2.856

Observations

1. As seen from the highlighted row in *Table* 1, the angle of incidence i_1 is equal to angle of emergence i_2 at the minimum deviation position.

2. As i_1 increases, as seen from equation (1), (i_2–D) decreases, i_2 decreases, D decreases till minimum deviation is reached and then increases.

3. As i_1 increases till minimum deviation is reached, Δi_2 is more than ΔD as seen from *Table* 2. Hence the emergent ray moves closer to the normal n_2 and once the minimum deviation position is crossed, the change in the angle of deviation (ΔD) starts increasing whereas the change in angle of emergence (Δi_2) further decreases. Hence the emergent ray starts moving away from n_2. Thus, the emergent ray retraces its path.

4. Angle of minimum deviation, $D_m = 37.18°$ can be seen from the *Table* 1. At this position, as seen from the highlighted row in *Table* 2, even if i_1 is varied by ± 4°, the change in the angle of deviation and the angle of emergence are too small to be noticed. Hence the emergent ray appears to have come to a halt even though the angle of incidence is changed, or in other words when the prism is rotated through small angles.

5. A similar argument can be made in case of a spectrum obtained from a polychromatic source of light instead of a monochromatic light.

A General Method to Find the Refractive Index of the Prism

Here is a method to determine the refractive index in any position of the prism.

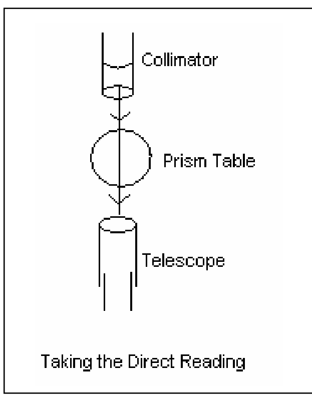
The refractive index of a prism is generally determined by placing it in the position of minimum deviation. But here is a method to determine the same in any position of the prism. Using this method one can determine r_1, r_2, i_2 and μ (*Figure* 1). In this method one has to measure the refracting angle of the prism A, angle of deviation D, and the angle of incidence i_1. This can be done as follows:

a. The angle of the prism is measured by the usual method with the help of the prism.

b. To measure the angle of incidence:

• In the absence of the prism, the slit of the collimator is focused through the telescope and direct reading is taken as shown in *Figure* 2.

• The prism is now kept on the prism table in a position, not necessarily the minimum deviation. The telescope is turned to focus the reflected image of the slit. The angle 'x' swept by the telescope is noted down (*Figure* 3).



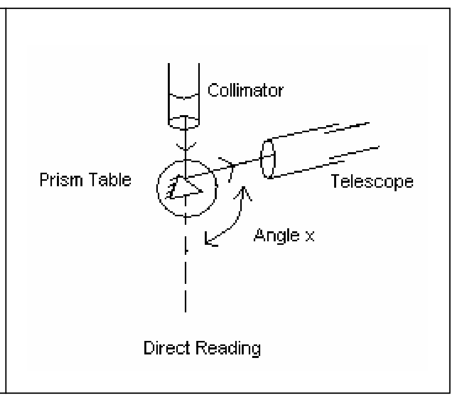


Figure 2 (left). Direct reading.
Figure 3 (right). Measuring i_1.

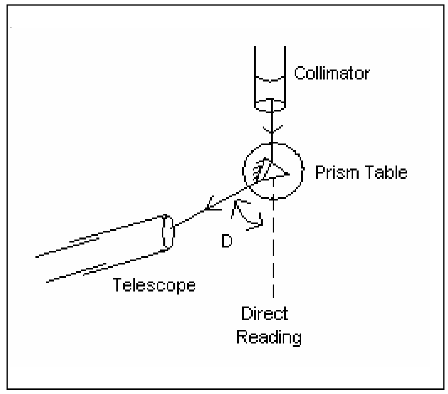


Figure 4. Measuring D.

- The angle of incidence i_1, is given by

$$i_1 = [90 - (x/2)] \quad (4)$$

c. To measure the angle of deviation:

Keeping the prism in the same position, the angle of deviation for a certain wavelength whose refractive index is to be determined is measured by focusing it through the telescope as shown in *Figure* 4.

Now we know the angle of incidence i_1, refracting angle of the prism A, and the angle of deviation D.

The angle of emergence i_2 can be determined using the formula

$$i_2 = D + A - i_1 \quad (5)$$

which follows from equation (1).

From Snell's Law, we know that

$$\frac{\sin i_1}{\sin r_1} = \mu . \quad (6)$$

Similarly,

$$\frac{\sin i_2}{\sin r_2} = \mu .$$

Therefore,

$$\frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2}\,. \tag{7}$$

We know that

$$A = r_1 + r_2,$$

which implies that

$$r_2 = A - r_1 \tag{8}$$

Therefore,

$$\frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin (A - r_1)}\,. \tag{9}$$

Now, the only unknown in equation (9) is r_1 which can be determined. From this r_1, we can find out the refractive index μ using equation (6).

Conclusion:

1. The refractive index of a prism can be determined not only in the minimum deviation position of the prism but also in any other suitable position.

2. In addition to the refracting angle of the prism and the angle of deviation, if one measures the angle of incidence, then the angles of refraction at the first and the second surface i.e, r_1 and r_2 can also be determined.

Why is the Minimum Deviation Position Always Used?

1. When the prism is kept in the minimum deviation position, the width of the spectral line is minimum, which is equal to the slit width. But when the prism is moved away from the minimum deviation position, the line width increases. Now the refractive index can be determined anywhere along the width of the line. Hence, there is uncertainty in the refractive index. Larger the

The refractive index of a prism is always determined in the minimum deviation position.

angle of deviation, more is the width of the line. Hence the uncertainty increases with the increase in angle of deviation.

2. At the minimum deviation position, $i_1 = i_2$. This reduces Snell's law to a much simpler form

$$\frac{\sin[(A+D_{\mathrm{m}})/2]}{\sin[A/2]} = \mu ,$$

where one needs to measure A and D_{m} and not i_1.

Hence, the refractive index of a prism is always determined in the minimum deviation position.

Remarks

A theoretical discussion of the angular response of the spectrum and the importance of the minimum deviation position has been presented here. It would be an interesting experiment to calculate the uncertainty in the refractive index, for a given wavelength, with the increase in the angle of deviation. Though I tried doing this experiment, I could not come out with good results as the least count of the spectrometer (which is 1') was the constraint in the measurement of accurate values of refractive indices. Hence, such an experiment cannot be carried out with the spectrometers, which are used in labs of colleges, to determine the refractive index. A study of the variation of the angle of emergence (i_2) and the variation of the angle of deviation (D), with the wavelength would help us in understanding the variations in the width of the spectral line, hence the spectrum, with the variations in the angle of incidence and the angle of deviation.