PRISM SPECTROMETER

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1. Aim

We try to calculate the Refrative Index of the Prism for various wavelengths of the Mercury Spectrum and then plot a Dispersion and Calibration Curves using a Prism Spectrometer.

2. Theory

The spectrometer is an instrument for analyzing the spectra of radiations. The glass-prism spectrometer is suitable for measuring ray deviations and refractive indices. Sometimes a diffraction grating is used in place of the prism for studying optical spectra. A prism refracts the light into a single spectrum, whereas the diffraction grating divides the available light into several spectra. Because of this, slit images formed using a prism are generally brighter than those formed using a grating. Spectral lines that are too dim to be seen with a grating can often be seen using a prism. Unfortunately, the increased brightness of the spectral lines is offset by a decreased resolution, since the prism doesn't separate the different lines as effectively as the grating. However, the brighter lines allow a narrow slit width to be used, which partially compensates for the reduced resolution.

With a prism, the angle of refraction is not directly proportional to the wavelength of the light. Therefore, to measure wavelengths using a prism, a calibration graph of the angle of deviation versus wavelength must be constructed using a light source with a known spectrum. The wavelength of unknown spectral lines can then be interpolated from the graph. Once a calibration graph is created for the prism, future wavelength determinations are valid only if they are made with the prism aligned precisely as it was when the graph was produced. To ensure that this alignment can be reproduced, all measurements are made with the prism aligned so that the light is refracted at the angle of minimum deviation.

The light to be examined is rendered parallel by a collimator consisting of a tube with a slit of adjustable width at one end and a convex lens at the other. The collimator has to be focused by adjusting the position of the slit until it is at the focal point of the lens. The parallel beam of light from the collimator passes through a glass prism standing on a prism-table which can be rotated, raised or lowered, and levelled. The prism deviates the component colors of the emitted light by different amounts and the spectrum so produced is examined by means of a telescope, which is mounted on a rotating arm and moves over a divided angular scale.

The theory of the prism spectrometer indicates that a spectrum of maximum definition is obtained when the angular deviation of a light ray passing through the prism is a minimum. Under such conditions it can be shown that the ray passes through the prism symmetrically. For a given wavelength of light traversing a given prism, there is a characteristic angle of incidence for which the angle of deviation is

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a minimum. This angle depends only on the index of refraction of the prism and the angle between the two sides of the prism traversed by the light. The relationship between these variables is given by the equation:

$$n = \frac{\sin((A + \delta_m)/2)}{\sin(A/2)}$$

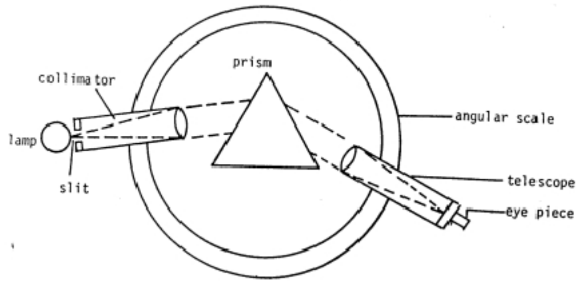
where n is the index of refraction of the prism; δ_m is the angle between the sides of the prism traversed by the light; and is the angle of minimum deviation. Since n varies with wavelength (i.e., $n = n()$), the angle of minimum deviation also varies, but it is constant for any particular wavelength.

The telescope can also be locked or moved very slowly by a fine adjustment screw and the instrument is provided with a heavy base for stability. To obtain sharp spectral lines the slit width should be quite small, about 0.1-0.3 mm.

The amount by which the visible spectrum spreads out into its constituent colors depends on how rapidly the refractive index of the prism material varies with the wavelength of the radiation, i.e.$dn/d\lambda$. This quantity is called the **dispersion** and is of prime importance in spectroscopy, since if the dispersion is small, radiation of slightly differing wavelengths cannot be resolved into separate and distinct spectral lines.

3. Procedure

The Setup



- First the telescope has to be focussed distant objects i.e infinity and this has to be maintained until the experiment is over, so as not to refocus again. Then, the cross-wires should be focussed by moving the eye-piece of the telescope.
- Adjust the Collimater such that the image seen in the telescope is sharp of the slit without the prism.
- **Measuring the Angle of Prism**A**:** Place the prism on the Prism Table and lock the prism table in the position so the the incident beam falls on one of the edges of the prism. Now, move the telescope and locate the images of the slit and note down the Angles. The difference beteen both the angles is $2A$. Hence, half of the diffece will give us A.
- Now, choose an angle of incidence other than the preious chosen one and with eye locate aprroximately the angle at which the spectrum starts to move in the opposite direction as the prism table is rotated, and lock the prism table. Now, using the telescope, fix the telescope on one of the sprectrum lines, and then use the fine adjustment for the movement of prism tabe to move the table so that we get the precise location of the angle where the line starts to move in the opposite direction, and note the angle for this.
- Without disturbing anything, remove the prism and get the measure of the angle of the direct image of the slit in the telescope. The difference betwen

these two angles is the Angle of Minimum Deviation δ_m for this spectral line λ. Repeat the same for all the spectral lines that are given by the mercury lamp.

- From above data we can calculate the refractive index n of the prism for various wavelengths. For the *Calibration Curve*, plot a graph of δ_m versus λ. For the *Dispersion Curve*, plot a graph of n versus λ.
- We can also calculate the Cauchy's constants A and B by doing a least squares fit of the data to the Cauchy Formula $n = A + \frac{B}{\lambda^2}$. We can also calculate the Resolving Power(R) of the prism using the two yellow lines of the mercury spectrum as $R = \frac{\lambda}{d\lambda}$ where $\lambda = (\lambda_1 + \lambda_2)/2$ and $d\lambda = \lambda_2 - \lambda_1$.

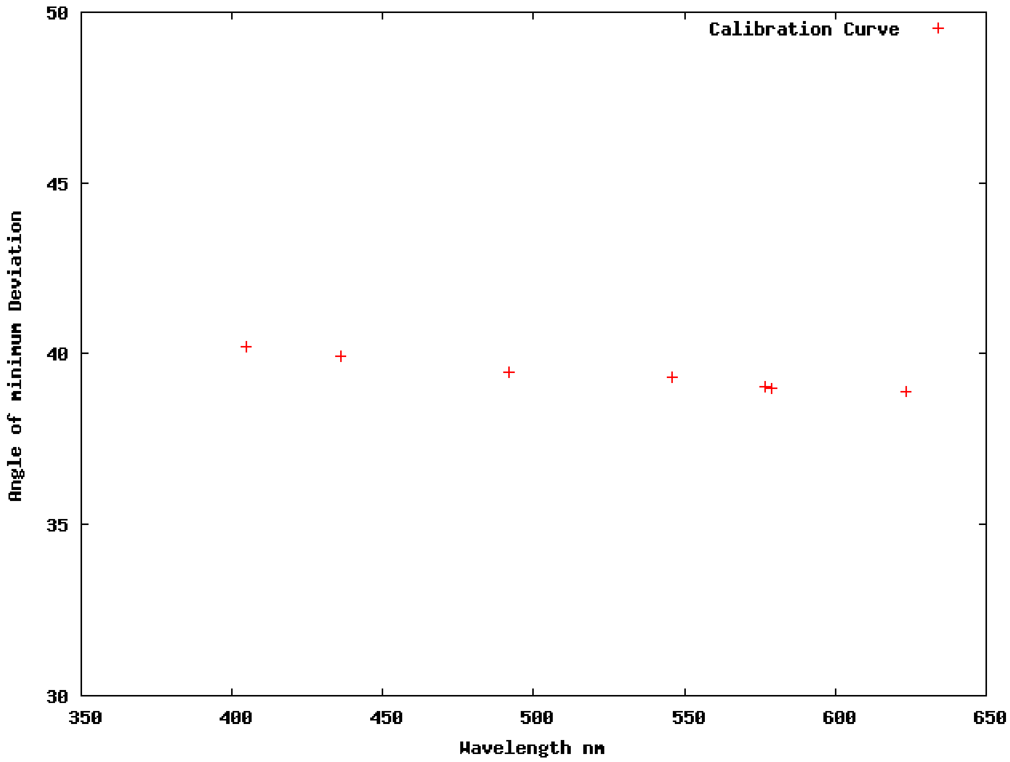
4. Observations and Results

- **The Spectrum:**The Spectrum obtained for the Mercury lamp that was visible with the reolution of the prism is as follows, given from Left to Right as observed:
  Red (Weak, 623.437nm),Yellow1(Weak,579.065nm), Yellow2(Strong,576.959nm),Green(Very Strong, 546.074nm),Blue Green(Very Weak,491.604nm),Blue(Very Strong,435.835nm), Violet(Strong,404.656nm). All the reported wavelength values are information that was gathered from books and articles.
- **Angle of the Prism:** The measured angle i.e $2A =$. Hence, the angle of the prism$A =$
- **The angles of minimum deviation and the Refractive index of the prism of the various wavelenghts**

S.No	Wavelength λ nm	Angle of Minimum Deviation δ_m	Refactive index n
1	623.437	$38^o54'$	1.522
2	579.065	$38^o59'$	1.523
3	576.959	$36^0 2'$	1.524
4	546.074	$39^o19'$	1.527
5	491.604	$39^o29'$	1.529
6	435.835	$39^o56'$	1.534
7	404.656	$40^o13'$	1.537

- From this, the Calibration and the Dispersion Curve was plotted for the data, and the graphs are given at the end of document.
- The behaviour of the Dispersion curve can be seen that the fall is not rapid over these range of wavlengths, hence, it is not a very heavily sloping line which implies that the dispersion of various spectral line donot vary a lot from each other i.e which is manifested by the closeness of the refractive index for the range of wavelengths.
- The Calibration Curve is almost a sraight line showing that the effect of wavelength on the Angle of Minimum Deviation is almost linear. This curve can help us in knowing the wavelength of a spectral line whose wavelength is unknown but the Angle of minimum Deviation measured using the same apparatus.

THE CALIBRATION CURVE



THE DISPERSION CURVE