电子科技大学
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Physics Lab Report

Experiment Title: Measurement of the Apex angle of a Prism and the Wavelength of Mercury Light Using a Spectrometer.

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Instructor: Jing Wu

Date Performed: 2017 September 17

Score

Abstract (About 100 words, 3 points)

The experiment can help us to measure the apex angle and the wave length of the mercury light.

First of all, we can use the autocollimation to make the telescope toward the apex directly. And then, we just switch the telescope and to make it toward the other side of the telescope directly, which can help us to get the angle of the apex with some simple calculation. We have learned the grating diffraction. We can use the grating to diffract the light and to get the wave length by using the formula we learned in physics in the last semester.

The results tell me the wave length of the light and the apex angle, which let me know how small the wave length is. The results also tell me that this special equipment and this method can help me to receive these answers.

Score

Introduction (3 points)

The experiment can help us to measure the apex angle and the wave length of the mercury light.

It also uses some special tricks or method to help us finish the experiment.

1. **Explain the function of the various component of a spectrometer.**

   Telescope: it can help us to let the telescope to toward the object directly. There is also arm to make this component switchable for reading the scale from a round ruler.

   Spectrometer table: to put the object on it in order to observe it. There are also three springs, which can help it to hold the leveling screw. There are also three nails which can adjust the high of this table and make sure it is horizontal. There are also some labels on the double side of this component, which is used to get the scale with the telescope component together.

   Collimator: it is use to produce the parallel beam in the direction toward the spectrometer table.

2. **Determine the apex angle of a class prism.**

   The angle of the class prime can be calculated by the formula

   $Angle = 180 - \Delta\theta$ (not radium but angle)

3. **Observe the spectrum of a mercury vapor lamp and record the angle**

of the deviation for the spectral lines.

We just record of yellow lines and two green lines, which can help us to get the angle. By this way, we can use the formula to calculate the wave length.

$$d sin\theta = m\lambda$$

Score

Experimental Procedure (State main steps in order of performance, 3 points)

The experiment can help us to measure the apex angle and the wave length of the mercury light.

1. Turn on the power of each component in this experiment.
2. Adjust the equipment and make sure the cross sharply.
3. Put the triangular prism on the center of the spectrometer table.
4. Let the telescope toward one side of the triangular prism and adjust the cross to the node of the crosshairs. Record the scale and switch the telescope to the other side and adjust the cross to the node of the crosshairs again for preparing to record another scale.
5. Repeat the step 4 for 3 times.
6. Put every equipment back to the right place and processing the data and write the report.

1. Turn on the power of each component in this experiment.
2. Adjust the equipment and make sure the cross sharply and adjust the cross to the node of the crosshairs at any position when switching the telescope.
3. Put the grating on the table and switch the telescope to record the scale when it turns to the two yellow vertical lines and two green lines and again two yellow lines respectively.
4. Repeat the step 3 for 2 times.
5. Put every equipment back to the right place and processing the data and write the report.

Score

Results (Data tables and figures, 2 points)

DATA TABLE 2-1 (*purpose*: to measure the apex angle of a prism)

Instrument error: 1’

Position of telescope	Left side (position 1)		Right side (position 2)	
Trial	Vernier 1	Vernier 2	Vernier 1	Vernier 2
	θ_1 (°, ')	θ_1'(°, ')	θ_2(°, ')	θ_2'(°, ')
1	315° 0'	134° 51'	194° 59'	14° 59'
2	315° 30'	135° 29'	195° 28'	15° 23'
3	315° 31'	135° 22'	195° 29'	15° 29'
Averaged	315° 20'	135° 14'	195° 18'	15° 17'

DATA TABLE 2-2 (*purpose*: to measure the wavelengths of lines in the spectra of mercury)

Diffraction order	k=-1(left side)						k=+1(right side)					
Lines	Yellow 2		Yellow 1		Green		Green		Yellow 1		Yellow 2	
Trial	$\varphi_{Y\text{-}L21}$	$\varphi_{Y\text{-}L22}$	$\varphi_{Y\text{-}L11}$	$\varphi_{Y\text{-}L12}$	$\varphi_{G\text{-}L1}$	$\varphi_{G\text{-}L2}$	$\varphi_{G\text{-}R1}$	$\varphi_{G\text{-}R2}$	$\varphi_{Y\text{-}R11}$	$\varphi_{Y\text{-}R12}$	$\varphi_{Y\text{-}R21}$	$\varphi_{Y\text{-}R22}$
1	290° 57'	115° 15'	291° 1'	111° 14'	290° 28'	118° 32'	261° 4'	81° 22'	260° 22'	80° 36'	260° 15'	80° 30'
2	290° 4'	110° 21'	289° 58'	110° 10'	289° 16'	119° 28'	262° 4'	84° 21'	263° 24'	82° 40'	261° 23'	81° 34'
Averaged	290° 30'	110° 48'	289° 59'	110° 42'	289° 52'	119° 0'	261° 34'	82° 51'	261° 53'	81° 51'	260° 49'	80° 2'

Score

Discussion (More than 150 words, 5 points)

The results were got by doing this experiment.
During this experiment, I use a lot of knowledge on high school mathematical about circle and angle. Base on this, I could finally get the right result from this equipment and minimize the system error. More than that, in the second part of this experiment, I also use some physics basic knowledge and equation to get the answer of the wave length.
In this experiment, I also learn to use the calipers, especially the method to use it as we read plenty of scales by using this method.
The data obtained by our group is great. At least, it looks great. We obtain them by experiments and with the use of mathematical tricks. The system error is minimized and the data in this sheet looks normal. There is no mistake or wrong parts because the scales in the same column is close.

Score

Conclusions (About 50 words, 2 points)

6.1 Compute the apex angle of a prism and its uncertainty

(1) The apex angle: $\bar{A} = 180° - \frac{1}{2}[|\overline{\theta_1} - \overline{\theta_2}| + |\overline{\theta_1'} - \overline{\theta_2'}|]$

(Note: If the difference between the two angles is about 240 degrees, the difference should be subtracted by 360°. For example, $\overline{\theta_1} = 355°45'$ and $\overline{\theta_2} = 115°43'$, their difference is not $355°45' - 115°43' = 240°2'$ but $360° - (355°45' - 115°43')$=119°58′).

$\boldsymbol{\bar{A} = 60^{\circ}1'50'' = 1.048\, rad}$

(2) The type A evaluation of uncertainty in θ_1, θ_1', θ_2, θ_2'.

$\boldsymbol{\sigma\theta_{A1} = 0.012\, rad}$

$\boldsymbol{\sigma\theta'_{A1} = 0.007\, rad}$

$\boldsymbol{\sigma\theta_{A2} = 0.007\, rad}$

$\boldsymbol{\sigma\theta_{A2}{}' = 0.007\, rad}$

(3) The type B evaluation of uncertainty in θ_1, θ_1', θ_2, θ_2'.

$\boldsymbol{\sigma\theta_{B1} = 0.0002\, rad}$

$\boldsymbol{\sigma\theta'_{B1} = 0.0002\, rad}$

$\boldsymbol{\sigma\theta_{B2} = 0.0002\, rad}$

$\boldsymbol{\sigma\theta_{B2}{}' = 0.0002\, rad}$

(4) The combined uncertainty in θ_1, θ_1', θ_2, θ_2'.

$\boldsymbol{\sigma\theta_1 = 0.0120\, rad}$

$\boldsymbol{\sigma\theta_1' = 0.0070\, rad}$

$\boldsymbol{\sigma\theta_2 = 0.0070\, rad}$

$\boldsymbol{\sigma\theta_2' = 0.0070\, rad}$

(5) The uncertainty in apex angle A: $\sigma_A = \frac{1}{2}(\sqrt{\sigma_{\theta 1}^2 + \sigma_{\theta 1'}^2 + \sigma_{\theta 2}^2 + \sigma_{\theta 2'}^2})$

$\boldsymbol{\sigma_A = \frac{1}{2}(\sqrt{\sigma_{\theta 1}^2 + \sigma_{\theta 1'}^2 + \sigma_{\theta 2}^2 + \sigma_{\theta 2'}^2})}$**=0.0085 rad**

(6) The final result of the apex angle: $A = \bar{A} \pm \sigma_A$

$\boldsymbol{A = \bar{A} \pm \sigma A = 1.048 \pm 0.0085\, rad}$

The calculation steps are in the appendix.

6.2 Compute the wavelengths of yellow doublet lines

(1) The diffraction angles of spectral lines of green, yellow doublet tint. For example, for green line,

$$\bar{\varphi} = \frac{1}{4}(|\varphi_{G-L1} - \varphi_{G-R1}| + |\varphi_{G-L2} - \varphi_{G-R2}|)$$

$\boldsymbol{\bar{\varphi}_G = 14^\circ 17' 37.5'' \approx 0.2495\, rad}$

$\boldsymbol{\bar{\varphi}_{Y1} = 14^\circ 36' 37.5'' \approx 0.2551\, rad}$

$\boldsymbol{\bar{\varphi}_{Y2} = 14^\circ 36' 52.5'' \approx 0.2551\, rad}$

(2) The diffraction space d, $d = \frac{\lambda_{green}}{sin\varphi_{green}}$ (λ_{green}=546.07 nm).

$\boldsymbol{d = \frac{\lambda_{green}}{sin\varphi_{green}} \approx 2211.77nm}$

(3) The wavelengths of yellow doublet lines, $\lambda_{Y1} = d \times sin\varphi_{Y1}$; $\lambda_{Y2} = d \times sin\varphi_{Y2}$

$\boldsymbol{\lambda_{Y1} = d \times sin\varphi_{Y1} \approx 557.907}$**nm**

$$\lambda_{Y2} = d \times sin\varphi_{Y2} \approx 558.063nm$$

(4) The relative error of λ_{Y1} *and* λ_{Y2}. Find the accepted values in Fig. 2-12.

$$e_{Y1} = \frac{\lambda_{Y2}\text{-}577}{577} \times 100\% \approx \text{-}3.31\%$$

$$e_{Y2} = \frac{\lambda_{Y2}\text{-}579}{579} \times 100\% \approx \text{-}3.62\%$$

The calculation steps are in the appendix.

Score

References (1 points)

Some parts of my report was got from the book (Introductory physics experiments for undergraduates, Haofu)

Some picture and some is written by searching and understanding the materials from baidu.com.

Some of the words and formulas are copy from materials on BB9.

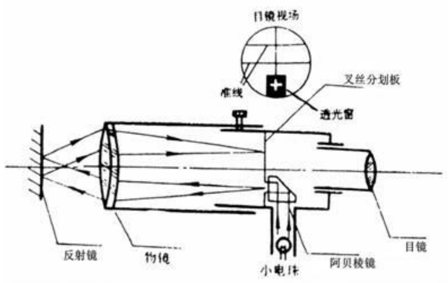
Calculations were down by my partner Yue and me Musk.

Score

Answers to Questions (6 points)

1. **When the image of the cross coincides with the upper node of the crosshairs we say that the prism, the telescope, and they are autocollimation. Why?**

   Because of that autocollimation component, it could help us to make sure the telescope toward the objective directly and on the same level. Because the objective is ideal vertical and the beam generated by the electronic device in the telescope spread toward that vertical objective. After reflection, it back to the telescope and should also focusing in the telescope (at upper level line). Only the telescope toward the object vertically, the reflected beam would focus on the upper level line as the beam generator is symmetry to the upper line about the middle line.



2. **How can you adjust the collimator to produce a parallel beam of light?**

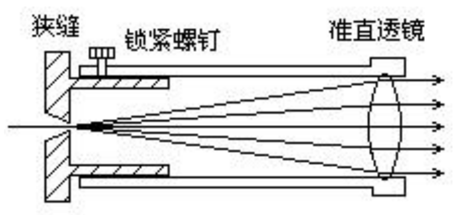


图5 平行光管光路

Rotate the focus knob of the collimator to see the image of the slit, adjust the screw on the slit to change the width of zero-order line and set it about 0.5mm. The collimator is then producing a parallel beam.

3. **For a spectrometer, the eccentric deviation is the inconsistency between the center of the prism table and that of the dial disk. In Fig. 3,9-16, O is the center of the dial disk and O' is the center of the prism table.**

- **Prove that $\boldsymbol{\varphi = \frac{1}{2}(\varphi_{1-}\varphi_{2\varphi})}$**

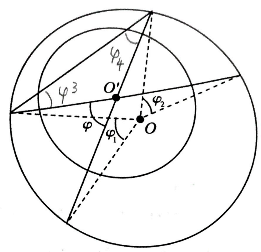


Fig. 3.9-16 The diagram of eccentric deviation

$\varphi = \varphi_3 + \varphi_4$

$\varphi_1 = 2\varphi_4 \quad \varphi_2 = 2\varphi_3 \quad \frac{1}{2}(\varphi_1 + \varphi_2) = \varphi_3 + \varphi_4$

so $\varphi = \frac{1}{2}(\varphi_1 + \varphi_2)$

- **Use the conclusion to explain why there are two visions on the dial**

disk.

Because the center of the dial of spectrometer and the rotating spindle can't be strictly coincidence. If only read one scale, it would definitely produce a system error, the eccentric error. If the two completely symmetrical cursor plate reading at the same time, is one of the eccentric error is positive, and the other is negative, and the absolute value of them are equal in size, this eliminates the eccentric error. So our φ is right when we use $\varphi = \frac{1}{2}(\varphi_{1-}\varphi_{2\varphi})$ and read two scales.

Appendix

Score

(Calculations, 15 points)

This is the calculation for the Conclusion, which was written by me and my partner.

Calculated by me and my partner.

$\bar{\theta}_1 = 315°20'20'' \approx 5.5\,rad$ $\qquad$ $\bar{\theta}_1' = 135°14' \approx 2.36\,rad$

$\bar{\theta}_2 = 195°18'40'' \approx 3.41\,rad$ $\qquad$ $\bar{\theta}_2' = 15°17' \approx 0.27\,rad$

$$\bar{A} = 180° - \frac{1}{2}\left[|\bar{\theta}_1 - \bar{\theta}_2| + |\bar{\theta}_1' - \bar{\theta}_2'|\right]$$

$$= 180° - 119°58'10'' = 60°1'50'' \approx 1.048\ rad$$

$\Delta\theta_{1A} = 0.012\ rad$ $\quad$ $\Delta\theta_{1A}' = 0.007\ rad$

$\Delta\theta_{2A} = 0.007\ rad$ $\quad$ $\Delta\theta_{2A}' = 0.007\ rad$

$\Delta_{仪} = 0°1'0'' \approx 0.0003\ rad$

$\Delta\theta_{1B} = \Delta\theta_{2B} = \Delta\theta_{1B}' = \Delta\theta_{2B}' = \frac{\Delta_{仪}}{\sqrt{3}} \approx 0.0002\,rad$

$\delta\theta_1 \approx 0.0120\ rad$ $\qquad$ $\delta\theta_1' \approx 0.0070\ rad$

$\delta\theta_2 \approx 0.0070\ rad$ $\qquad$ $\delta\theta_2' \approx 0.0070\ rad$

$$\delta A = \frac{1}{2}\sqrt{\delta\theta_1^2 + \delta\theta_1'^2 + \delta\theta_2^2 + \delta\theta_2'^2} \approx 0.0085\,rad$$

$$A = \bar{A} \pm \delta A = 1.048 \pm 0.0085\ rad$$

$$\bar{\varphi}_G = \frac{1}{4}\left(|\varphi_{G-L_1} - \varphi_{G-R_1}| + |\varphi_{G-L_2} - \varphi_{G-R_2}|\right) = 14°17'37.5' \approx 0.2495\,rad$$

$$\varphi_{Y_1} = \frac{1}{4}\left(|\varphi_{Y-L_{11}} - \varphi_{Y-R_{11}}| + |\varphi_{Y-L_{12}} - \varphi_{Y-R_{12}}|\right) = 14°36'37.5' \approx 0.2551\,rad$$

$$\varphi_{Y_2} = \frac{1}{4}\left(|\varphi_{Y-L_{21}} - \varphi_{Y-R_{21}}| + |\varphi_{Y-L_{22}} - \varphi_{Y-R_{22}}|\right) = 14°36'52.5' \approx 0.2551\,rad$$

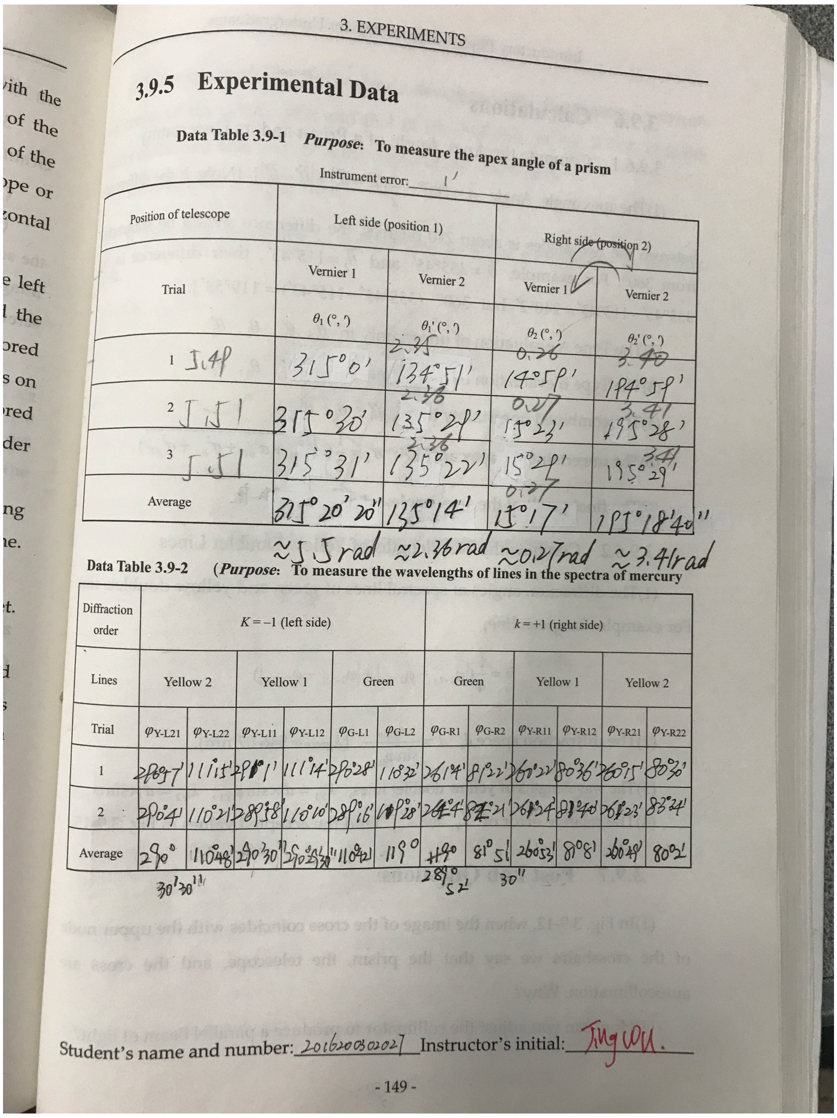
$$d = \frac{\lambda_{green}}{\sin\varphi_G} \approx 2211.77\ nm$$

$\lambda_{Y_1} = d \times \sin\varphi_{Y_1} \approx 557.907\ nm$ $\qquad$ $\lambda_{Y_2} = d \times \sin\varphi_{Y_2} \approx 558.063\,nm$

$e_{Y_1} = \frac{\lambda_{Y_1} - 577}{577} \times 100\% \approx -3.31\%$ $\qquad$ $e_{Y_2} = \frac{\lambda_{Y_2} - 579}{579} \times 100\% \approx -3.62\%$

Appendix

(Scanned data sheets)



3. EXPERIMENTS

3.9.5 Experimental Data

Data Table 3.9-1 ***Purpose***: To measure the apex angle of a prism

Instrument error: 1'

Position of telescope	Left side (position 1)		Right side (position 2)	
Trial	Vernier 1	Vernier 2	Vernier 1	Vernier 2
	θ_1 (°, ′)	θ_1' (°, ′)	θ_2 (°, ′)	θ_2' (°, ′)
1 5.48	315°0'	2.35 134°51'	0.26 14°58'	3.40 184°58'
2 5.51	315°30'	2.36 135°28'	0.27 15°23'	3.41 195°28'
3 5.51	315°31'	2.36 135°22'	15°29' 0.27	3.41 195°29'
Average	315°20'20''	135°14'	15°17'	195°18'40''
	≈5.5rad	≈2.36rad	≈0.27rad	≈3.41rad

Data Table 3.9-2 (***Purpose***: To measure the wavelengths of lines in the spectra of mercury

Diffraction order	$K=-1$ (left side)						$k=+1$ (right side)					
Lines	Yellow 2		Yellow 1		Green		Green		Yellow 1		Yellow 2	
Trial	$\varphi_{Y\text{-}L21}$	$\varphi_{Y\text{-}L22}$	$\varphi_{Y\text{-}L11}$	$\varphi_{Y\text{-}L12}$	$\varphi_{G\text{-}L1}$	$\varphi_{G\text{-}L2}$	$\varphi_{G\text{-}R1}$	$\varphi_{G\text{-}R2}$	$\varphi_{Y\text{-}R11}$	$\varphi_{Y\text{-}R12}$	$\varphi_{Y\text{-}R21}$	$\varphi_{Y\text{-}R22}$
1	289°57'	111°15'	290°1'	111°14'	290°28'	110°32'	261°4'	81°22'	260°22'	80°36'	260°15'	80°30'
2	290°4'	110°21'	289°38'	110°10'	289°16'	110°28'	261°4'	81°21'	261°24'	81°40'	261°23'	83°24'
Average	290° 30'30''	110°48'	290°30''	290°23'30''	110°42'	119°	~~119°~~ 289°52'	81°51' 30''	260°53'	81°8'	260°49'	80°2'

Student's name and number: 2016200302027 Instructor's initial: Jing Wu.

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Some wrong trying

$\bar{\theta}_1 = 315^\circ 20' 20''$ $\approx 5.5\,\text{rad}$ $\quad \bar{\theta}_1' = 135^\circ 14'$ $\approx 2.36\,\text{rad}$ $\quad \bar{\theta}_2 = 15^\circ 17'$ $\approx 0.27\,\text{rad}$ $\quad \bar{\theta}_2' = 195^\circ 98' 40''$ $\approx 3.41\,\text{rad}$

$$\bar{A} = 180 - \frac{1}{2}[\,|\bar{\theta}_1 - \bar{\theta}_2| + |\bar{\theta}_1' - \bar{\theta}_2'|\,] = 60^\circ$$

$$= 180^\circ - \frac{1}{2}\left[\,|360^\circ - (315^\circ 20' 20'' - 15^\circ 17')| + |135^\circ 14' - 195^\circ 18' 40''|\,\right]$$

$$= 180^\circ - \frac{1}{2}\left[\,|360^\circ - 300^\circ 3' 20''| + 60^\circ 4' 40''\,\right]$$

$$= 180^\circ - \frac{1}{2}\left[\,59^\circ 56' 40'' + 60^\circ 4' 40''\,\right]$$

$$= 180^\circ - \frac{1}{2} \times 120^\circ 1' 20''$$

$$= 180^\circ - 60^\circ 0' 40''$$

$$=$$

$$\bar{A} = 180^\circ - 119^\circ 58' 10'' = 60^\circ 1' 50'' = 1.048$$

$\Delta\theta_{1A} = 0.012 \qquad \Delta\theta_{1A}' = 0.007$

$\Delta\theta_{2A} = 0.007 \qquad \Delta\theta_{2A}' = 0.007$

$\Delta\theta_{1B} = \Delta\theta_{1B}' = \Delta\theta_{2B} = \Delta\theta_{2B}' = 1' = 0.0003$

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$\Delta\theta_1 = \cancel{0.0217}$ 0.0120 $\quad \Delta\theta_1' = 0.0070$

$\Delta\theta_2 = 0.0070 \quad \Delta\theta_2' = 0.0070$

$\delta_A = 0.0085$

$A = \bar{A} \pm \delta_A = 1.048 \pm 0.0085 = 1.048 \pm 0.0085$ rad