(TA INITIALS)

FIRST NAME (PRINT) LAST NAME (PRINT) BROCK ID (AB17CD) (LAB DATE)

Experiment 5

Diffraction of light by a grating

Part 1: Determining the spacing of a diffraction grating

In this part of the experiment you will determine the spacing d of lines on a glass grating by passing a laser beam through it and examining the diffraction pattern projected on a screen.

The laser beam is parallel and monochromatic, with wavelength

$$\lambda \pm \Delta\lambda = 632.8 \pm 0.5 \text{ nm}.$$

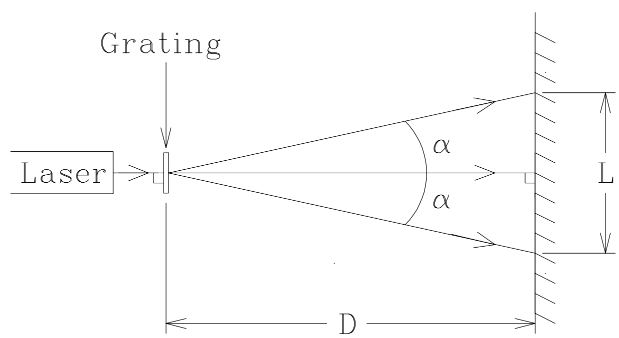

Figure 5.1: Experimental setup for Part 1.

- Check that the screen and grating surface are perpendicular to the incident beam, and measure the distance D between the grating and the screen, as shown in Figure 5.1.

  $D =$ . . . . $\pm$ . . . . .m

$\boxed{?}$ What do you note in the diffraction pattern as you slowly rotate the grating? Based on your observation, if the grating was set to some angle θ from being perpendicular to the beam, how would you adjust your L values to account for this offset?

- Mount a sheet of graph paper on the screen and carefully mark the series of interference maxima. Identify the straight path $m = 0$ maximum. Measure the distance L *between the centres* of pairs of spots of order m, ($+m$ to $-m$) for $m = \pm 1$ to $m = \pm 10$. Record your results in Table 5.1.
- With L and D measured, the relationship between these variables and the angle α in Figure 5.1 is given by

$$\tan(\alpha) = L/2D. \tag{5.1}$$

  If $L/2 \ll D$ then $\alpha \approx 0$ and $\sin\alpha \approx \tan\alpha$. Equating these two terms in Equations 5.1 and 5.4 yields

$$d = 2m\lambda D/L. \tag{5.2}$$

- Calculate d for the ten measurements of L, then calculate an average value $\langle d \rangle$ and standard deviation $\sigma(d)$ of d and enter the results in Table 5.1.

m	L (m)	d (m)	$(d - \langle d \rangle)$ (m)	$(d - \langle d \rangle)^2$ (m)
± 1				
± 2				
± 3				
± 4				
± 5				
± 6				
± 7				
± 8				
± 9				
± 10				
		$\langle d \rangle =$	$variance =$	
		$\sigma(d) = \sqrt{variance}$		

Table 5.1: Calculation of $\langle x \rangle$ and $\sigma(x)$ for d. Here, variance$(x) = \sigma^2(x) = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \langle x \rangle)^2$.

- Close any running Physicalab programs, then start a new Physicalab session and enter your email address. Enter the d values as coordinates (m, d). Select **bellcurve** and **bargraph**, then click **draw** to display a distribution of your n values with the average $\langle d \rangle$ and standard deviation $\sigma(d)$ of the sample. Click **Send to:** to email yourself a copy of the graph.

- Verify that the results from the distribution are identical to those from Table 5.1. If they are not, you need to review your calculations. Report below the grating spacing for this grating:

$$d = \dots\dots\dots\dots \pm \dots\dots\dots\dots \text{m}$$

Part 2: Determining the wavelengths of the Balmer spectrum of H_2

The light source is a hydrogen discharge tube. This source illuminates a slit at one end of the collimator tube, and a lens at the other end makes a parallel beam of the light passing through the slit. The beam is diffracted by the grating and collected by the front lens of the telescope, which focuses the light on a set of cross-hairs.

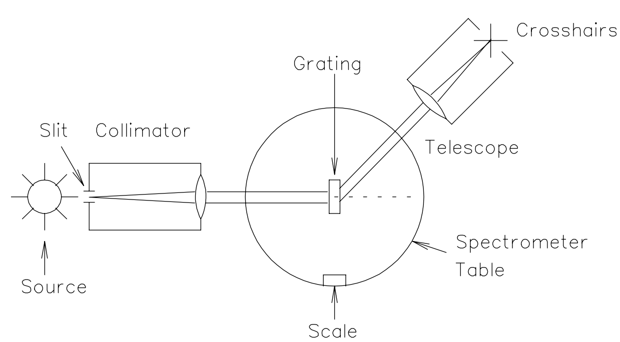

Figure 5.2: Experimental setup for part 2

If necessary, the image sharpness can be improved by rotating focusing knobs on the collimator and telescope. The slit width is adjusted with a screw on the collimator. The orientation of the crosshairs is set by rotating the telescope eyepiece. They should be oriented diagonally, like an X.

The telescope can rotate around the grating, its angular position with respect to an *arbitrary* zero given by an angular scale on the base of the instrument.

Note: To extend the life of the H2 discharge tube, keep it from overheating; turn it on for 30 seconds or less to adjust the crosshairs, then turn it off for at least 30 seconds while you read the Vernier scale.

Proceed as follows, remembering never to touch the grating as it is easily damaged.

- Switch on the H2 discharge tube. The lamp should emit a bright pink light. If the light looks grey, the tube is worn out. See the instructor.
- Check that the telescope locking screw located at the centre of the telescope base is loose, then slowly rotate the telescope assembly until you see a sharp pink image of the slit, Gently tighten the screw to lock the telescope in place.
- Turn the fine-adjust knob located on the right side of the telescope base to *place the centre of the crosshairs* on an edge of the slit image.
- Turn off the H2 discharge tube.

? Does it matter which edge of the image is used for reference? How does this choice affect the remainder of your experiment?

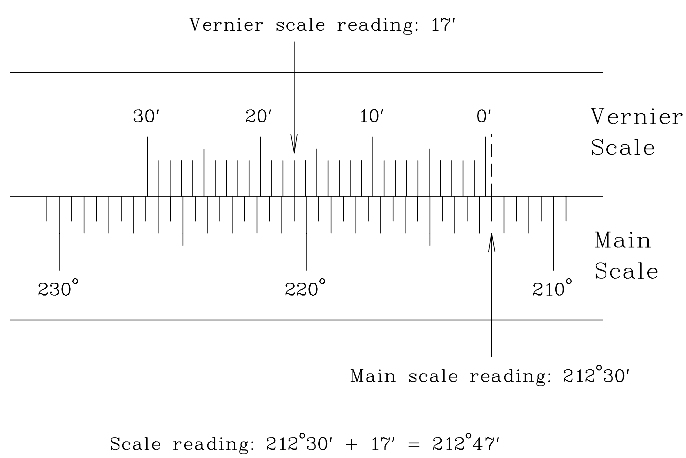

Figure 5.3: Example of Angular Vernier Scale Reading — 212°47′

- Read the position of the telescope from the angular scale on the base. This can be done to a precision of $1'$ ($\pm$ one minute, $60' = 1°$). To read the scale:
  1. Locate the "0" line on the vernier scale, and note which main scale division it is immediately after; e.g. $212°30'$ on the main scale in Figure 5.3. Note that the numbers on the main and vernier scales increase from right to left, and not from left to right as you are used to reading.
  2. Scan along the line where the main and vernier scales meet, and note which *one* vernier scale division is directly in line with a main scale division, e.g. $17'$ on the vernier scale in Figure 5.3.
  3. Add the main and vernier scale readings to obtain the angular scale reading, e.g. $212°30' + 17' = 212°47'$ in Figure 5.3.
- Enter your measurement in Table 5.2.

- Turn on the H2 lamp, then unlock the telescope and slowly rotate it to the right until the first violet slit image is in the field of view. Lock the telescope, and use the fine-adjust knob until the centre of the crosshairs is again situated *on the same edge* of the slit image as was used before.
- Turn off the H2 lamp, then read the position indicated on the angular scale. This is Violet(θ_{+1}), the angle of diffraction of the violet spectral line with $m = +1$.
- Turn on the H2 lamp, then unlock the telescope, rotate it to the left of center until the first violet image is seen again. Lock the telescope and centre the crosshairs again *on the same edge* of the slit image as was used before.
- Turn off the H2 lamp, then determine Violet(θ_{-1}), the angle of diffraction with $m = -1$.
- Repeat the above steps for the blue and violet spectral lines to complete the first line of Table 5.2.
- Convert your data values from degrees and minutes to decimal degrees, recalling that $1^\circ = 60'$, and enter these in the second row of Table 5.2.

	Pink (θ_0)	Violet (θ_{+1})	Violet (θ_{-1})	Blue (θ_{+1})	Blue (θ_{-1})	Red (θ_{+1})	Red (θ_{-1})
$^\circ$, $'$							
$^\circ$							

Table 5.2: Measurements for the spectral lines of H_2 in degrees and minutes, and also in decimal degrees

The diffraction angle $\alpha_{\pm1}$ for a particular colour is the measured angle of deviation $\theta_{\pm1}$ of that colour from the light's direct path reference angle θ_0. Calculating the difference between the angular positions of the pink and coloured lines will give you $\alpha_{\pm1}$, i.e.

$$\alpha_{\pm1} = |\theta_0 - \theta_{\pm1}| \tag{5.3}$$

- Calculate from the data in Table 5.2 the values of the diffraction angle $\alpha_{\pm1}$ for the three lines of the H_2 spectrum. There will be two results for each colour, $\alpha_{\pm1}$, one for each side of the reference angle θ_0. Calculate the average $\langle\alpha\rangle = \frac{1}{2}|\alpha_{+1} + \alpha_{-1}|$ of these two angles then estimate the error with $\Delta(\alpha) = \frac{1}{2}|\alpha_{+1} - \alpha_{-1}|$.

line	α_{+1}	α_{-1}	$\langle\alpha\rangle$	$\Delta(\alpha)$
Violet (α_V)				
Blue (α_B)				
Red (α_R)				

Table 5.3: Calculated diffraction angles for the spectral lines of H_2

The diffraction grating used in the spectrometer is made with a line density of

$$N \pm \Delta(N) = 600 \pm 1 \text{ lines/mm.}$$

This is *not* the same value as the grating spacing in Part 1. The line density and grating spacing are related by $d = 1/N$. The distance d between the lines and error $\Delta(d)$ for the grating used in this spectrometer is

$$d = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \text{ mm}$$

$$\Delta(d) = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots \text{ mm}$$

- Calculate a wavelength $\lambda(\alpha)$ and the associated error $\Delta(\lambda(\alpha))$ for the violet, blue and red spectral line of H_2. Angle errors *must* be expressed in radians. Record this data in Table 5.4.

$$\lambda_V = \frac{d}{m} sin(\alpha_V) = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\lambda_B = = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\lambda_R = = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\Delta(\lambda_V) = \lambda_V \sqrt{\left(\frac{\Delta(d)}{d}\right)^2 + \left(\frac{\cos(\alpha_V)\Delta(\alpha_V)}{sin(\alpha_V)}\right)^2} = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\Delta(\lambda_B) = = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\Delta(\lambda_R) = = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

- Use the Balmer Equation 5.5 to calculate the theoretical wavelengths $\lambda(Balmer)$ of the violet, blue and red lines of the H_2 spectrum. Append this data to Table 5.4.

$$\lambda_V(Balmer) = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\lambda_B(Balmer) = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$\lambda_R(Balmer) = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots$$

line	*transition*	$\lambda(\alpha)$	$\Delta(\lambda(\alpha))$	$\lambda(Balmer)$
violet				
blue				
red				

Table 5.4: Calculated $\lambda(\alpha)$ from angles $\langle\alpha\rangle$ and $\lambda(Balmer)$ from Equation 5.5

(!) Important! Be sure to have this printout signed and dated by a TA before you leave at the end of the lab session. All your work needs to be kept for review by the instructor, if so requested.

Lab report

Go to the “Lab Documents” web page to access the online lab report template for this experiment. Complete the template as instructed and submit it to Turnitin before the lab report submission deadline, late in the evening six days following your scheduled lab session. Do not wait until the last minute. Turnitin will not accept overdue submissions. Unsubmitted lab reports are assigned a grade of zero.