Diffraction Grating and Spectrometer

Purpose: Use the spectrometer to determine the spacing of a transmission diffraction grating using light with known wavelength

Introduction and Theory

A transmission diffraction grating is made by scratching equally spaced parallel lines into a piece of glass with a diamond. (The gratings you will be using are plastic copies of such a grating.) The clear spaces between the scratches act as multiple slits for the light to pass through. The most important parameter of a grating is the grating spacing *d*, which is the distance between the slits. When light with wavelength λ incidents on the grating, constructive interference (or bright lines) takes place at angles θ if

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

and destructive interference (or dark lines) takes place in between the bright lines, forming a series of bright and dark lines, called the spectrum.

The variable integer $m = 0, \pm1, \pm2, \ldots$ is called the order of the spectrum lines. The zeroth order spectrum ($m = 0$) corresponds to light that passes straight through ($\theta = 0$) and does not give much information. However, if we know the angles θ for higher order spectrum lines, we can determine the grating spacing from the wavelength of the incident light, or vice versa.

To measure the angles, a spectrometer is used. A spectrometer consists of a slit that the light will pass through, a collimator (a lens to make the light parallel), a diffraction grating, a movable telescope to focus the diffracted light, and a scale to measure the angle θ. See Fig 1.

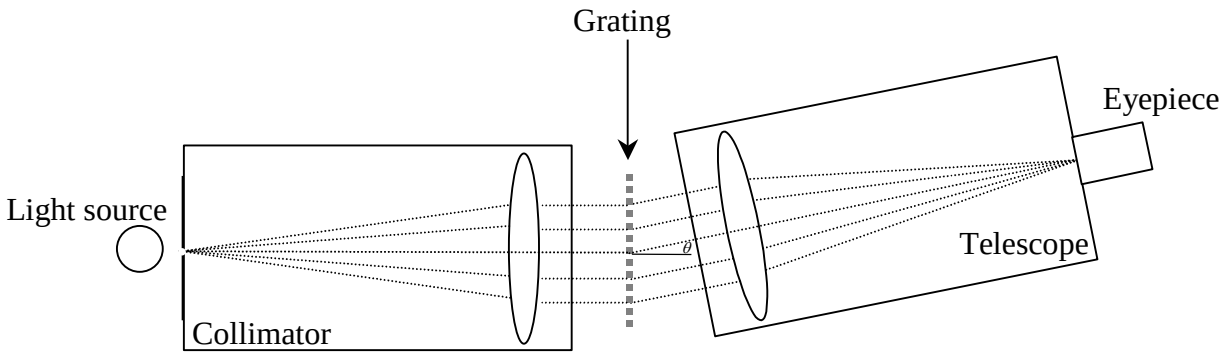

Fig 1

Because the bright lines happen at $m = 0, \pm1, \pm2, \pm3 \ldots$, the diffraction pattern is symmetric about $\theta = 0$. So the angle θ(m = 1) must be half of the angle between θ(m = 1) and θ(m = –1). This method does not need to locate $\theta = 0$, and is the method we are going to use in this lab.

The source is the light from a Hydrogen discharge tube. Hydrogen has 3 colours of emission lines at specific wavelengths (Balmer series). If you studied the Bohr model of the Hydrogen atom, you will

know how the Balmer series colours are produced. We can use the known wavelengths to determine the grating spacing.

To Determine the Grating Spacing

Apparatus: Spectrometer with diffraction grating, Hydrogen discharge tube, 6V DC power supply, wires.

Data

Familiarize yourself with the parts of the spectrometer before the lights get turned off. The hydrogen discharge tube is already installed in its stand. Connect the hydrogen discharge lamp to a 6V DC power supply and turn it on.

Align the slit on the discharge tube stand to the slit on the telescope. With the telescope at the straight through position, move the eyepiece of the telescope in and out to focus a clearly defined image of the slit. The image should appear as a vertical pink line. If you see multiple colours (blue and red), the lamp is not correctly aligned with the slit. Adjust the position of the lamp until you see a line of a single colour that is as bright as possible. You will also see a black hair-line that rotates with the eyepiece. This black line will be used to locate the positions of the spectral lines for measuring, so align it with the image.

Locate and measure the angles for the first bright red lines on either side of the straight through position. They are the first order lines $m = 1$ and $m = -1$. Because the angle marks are wide, you may be able to read to 1/5 of the smallest division instead of 1/2.

Calculations, Uncertainty Analysis and Conclusions

Calculate the angle θ for $m = 1$.

Calculate the grating spacing of your diffraction grating, together with uncertainties. The red line of hydrogen's Balmer series is $\lambda_{red} = (656.11 \pm 0.01)$ nm. State your result in the standard format.

The reference value for the diffraction grating spacing is: $d_{ref} = (1.693 \pm 0.001) \times 10^{-6}$m

Calculate the discrepancy (absolute and relative) between your value and the reference, and state if the results agree. Discuss.

Name: _____

Partner: _____

Desk: _____

Date: _____

Diffraction Grating and Spectrometer

Purpose: Calculate the diffraction grating spacing of the spectrometer using the Balmer series red hydrogen line.

Apparatus: Draw a labeled diagram of the spectrometer and discharge tube system and LIST and identify all equipment used

Data:

Table 1: Angle for the first order red hydrogen Balmer line (degrees)

	Angle (degrees)	Uncert (degrees)
n = 1		
n = -1		
average		

Comment on how you determined uncert:

Calculations:

Calculate the diffraction grating spacing:

Uncertainty Analysis:

Derive a relation for the relative uncertainty ($\delta d/d$) and the absolute uncertainty (δd) of the diffraction grating spacing:

Calculate $\delta d/d$ and δd

Conclusions:

The diffraction grating spacing of Spectrometer # _____ was measured to be _____ (± %).

Discussion:

Calculate the discrepancy (% and absolute) between your result and the reference value:

Do these values agree within uncertainty?

Discuss: