Experiment 7
Wavelength of Light (with a ruler)

SAFETY

Make sure that you have read the **General Safety Notes**, in the Introductory section of this book, before you begin.

Do not, **under any circumstances,** attempt to repair or dismantle any of the equipment. If you suspect equipment to be faulty, turn it off at the power point and talk to your demonstrator.

ADDITIONAL HAZARDS

Do not, under any circumstances look directly into the lasers as they can cause eye damage.

Outline of Experiment

In this experiment you will achieve the seemingly impossible and measure the wavelength of light using a ruler! This is a very famous physics experiment and illustrates the kind of lateral thinking required to adapt available equipment to produce a more accurate measurement using clever design. We use our knowledge of interference (which you do not need to have covered in lectures before the lab – we only need the most basic theory included below) and the conveniently spaced grooves on a metal ruler to produce an interference pattern where we can measure or know everything except the wavelength of the light source (which we will then be able to work out). We will be using laser diodes as a light source because we will want to use a single wavelength.

✓***Pre-lab exercises:*** *Read the laboratory exercise, complete the questions below, then submit the pre-lab task online (LMS or http://fyl.ph.unimelb.edu.au/prelabs) for this experiment. [Your marks for the pre-lab will be based on the answers to the online questions, which are taken from the pre-lab work in the manual]*

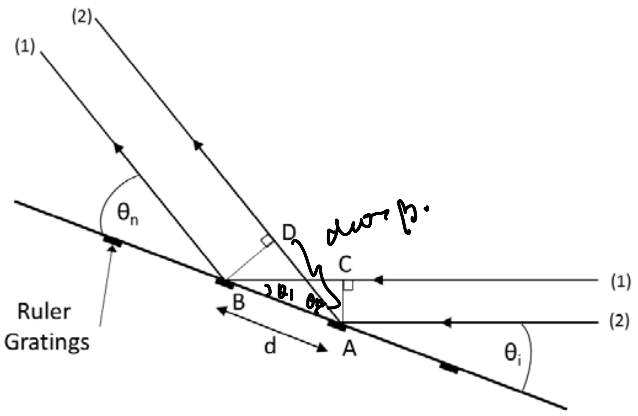
Learning Goals

- To undertake the careful setup of the experiment and obtain accurate results.
- To work efficiently as a team in your groups, sharing and contributing to all tasks.
- To use Excel efficiently for manipulating data through formulas.
- To critically compare results with the accepted value.
- To measure the wavelength of laser light using a ruler as a diffraction grating.

Introduction

Explore the idea of wave interference and diffraction grating at
https://en.wikipedia.org/wiki/Diffraction_grating

The light from the laser diode may be considered as parallel rays that are scattered (reflected) from the metal ruler in the spaces between the dark markings. In the diagram **below,** rays (1) and (2) are scattered from adjacent spaces.



Section A: Wavelength of Light

✓ **Pre-lab question 1**

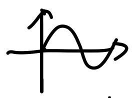
Write down an expression for the path difference (AD – BC) in terms of θ_n, θ_i and d from the above figure.

$AD = d \cdot \cos\theta_n$

$BC = d \cdot \cos\theta_i$

$AD - BC = d(\cos\theta_n - \cos\theta_i)$

✓ **Pre-lab question 2**



What is the physical condition for constructive interference? What does this mean for rays (1) and (2), which have the same wavelength?

$R_1 - R_2 = 0 + \cancel{2n\pi}$ $m\lambda$.

the phase difference between rays (1) and (2) are ~~2nπ~~ $m\lambda$.

✓ **Pre-lab question 3**

Equate these expressions to get a relation describing the structure of the interference pattern produced in this process. Check this with your demonstrator if you are uncertain about the equation that you have produced.

$\cancel{2n\pi} = d(\cos\theta_n - \cos\theta_i)$

$m\lambda$.

x y

$m\lambda = d(\cos\theta_n - \cos\theta_i)$.

$\lambda = \frac{d(\cos\theta_n - \cos\theta_i)}{m}$

$\cos\alpha \approx 1 - \frac{\alpha^2}{2}$

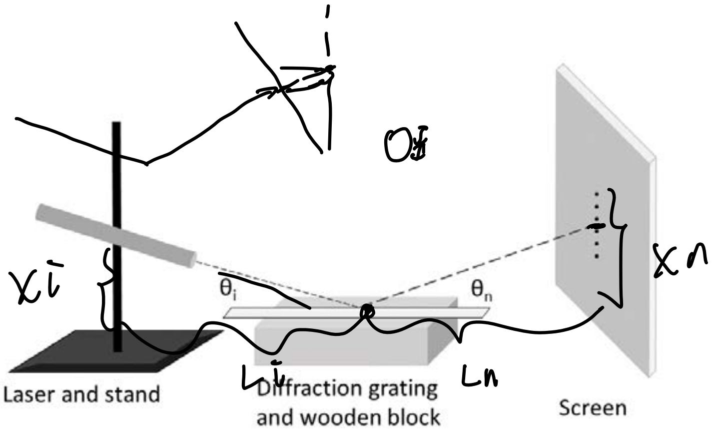
✓ **Pre-lab question 4**

Why do we want a light source of only one colour (wavelength) for this experiment? What would happen if we used a white light source? (if time permits you can experiment with this during the lab).

avoid other wavelength's light's interference

Experimental Set-up

Set up the experiment shown in the diagram. Using the spacings on the ruler create a diffraction pattern on the screen (Check with your demonstrator once you think you have the correct pattern). Observe and record the interference pattern that is produced on the screen (rough sketch of the pattern produced). (To indicate the relative intensity of the diffracted beams, you may wish to draw dots of varying diameter.)



✓ What do you notice when you change between the lines of 1 mm spacing and 0.5 mm spacing?

✓ Which will you use to get the best measurement for calculating the wavelength λ?

✓ Check that the laser beam is correctly aligned so it hits the spacings you chose.

Data

✓ Record the following quantities (include at least a rough estimate of your uncertainty – talk to your demonstrator if unsure):

- ✓ The length between ruler and screen is measured to be L_n
- ✓ The length between laser and ruler is measured to be L_i
- ✓ The height of the laser is measured to be X_i
- ✓ The height of the maxima, X_n

✓ The integer n labels the order of the diffracted beam, with the central (brightest) beam having n = 0. The quantities n should be the first in your table.

✓ Calculate the values θ_i and θ_n.

Analysis

✓ You should have an expression relating n to λ, d, cos (θ_n) and cos (θ_i) from Pre-lab question 3. Given that λ, d and cos (θ_i) are constants, how might you obtain λ from this data?

✓ Plot cos(θ_n) vs maxima (n), for experimental values. Use this to determine a value for the wavelength, λ.

Conclusion

✓ In your conclusion discuss how your wavelength value compares with the known value for these laser diodes (your demonstrators will tell you). Think about how you might improve the precision and accuracy of your measurement.