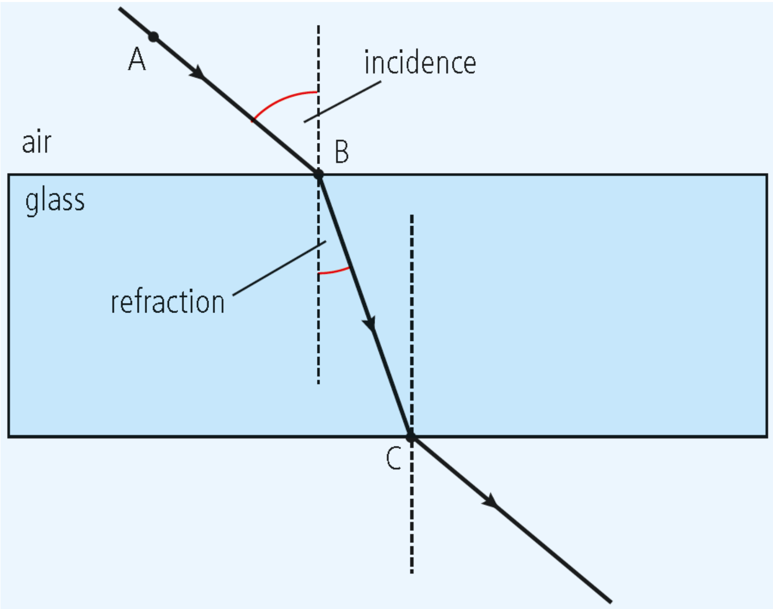
C.3 Wave phenomena

Measuring the refractive index of glass

Lab Worksheet

Introduction

In this experiment the refractive index of a glass block will be measured by tracing rays of light through it with pins. You could also do this with a ray of light from a laser pointer, but the results are probably better with pins.



Apparatus

- transparent block (you will probably be able to find one of these in your physics lab. If you want to try this at home you could use a block of gelatine (jelly/jell-o).
  Whatever you use, it must not be in a container since this will change the angle of refraction.)
- pins (large pins are best)
- a cork board (to avoid sticking pins in the table)
- protractor (to measure the angles)

Theory

According to Snell's law, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is equal to the inverse of the ratio of the refractive indices:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

But the refractive index of air is approximately 1, so if the light is travelling from air into the block:

$$\frac{\sin\theta_1}{\sin\theta_2} = n_2$$

Method

Place a plain piece of paper on the corkboard, then put the block in the middle and draw around it. Place one pin in the middle of the block on the side furthest from you. Place a second pin a bit further from the block, as illustrated by positions A and B in the diagram. Take a third pin and place it on your side of the block so that when you look through the block all the pins are in a line. Joining the dots will give the path of a ray of light through the block. Repeat this procedure for a range of different positions for pin A (there is no need to move pin B).

When you have at least five different sets of pin holes, take away the block and pins and join the dots. Use a protractor to measure the angles of incidence and refraction.

Collecting data

Enter your data into a spreadsheet ready for processing:

	A	B
1	Angle of incidence(°)	Angle of refraction(°)
2	±	±
3		
4		
5		

Estimate the uncertainty in your measurement of the angles.

Processing data

The spreadsheet can now be used to find the refractive index of the block and the uncertainty in the value by adding the following columns:

	A	B	C	D	E
1	Angle of incidence(°)	Angle of refraction(°)	sin θ_1	sin θ_2	n
2	±	±			
3					
4					

The formulae used are:

=SIN(A3*2*PI()/360) To calculate the sine of the angle of incidence.

Note that the angle has to be converted into radians.

=SIN(B3*2*PI()/360) To calculate the sine of the angle of refraction.

=C3/D3 to calculate the refractive index.

Use the spreadsheet to calculate the average of the values you have obtained for the refractive index.
The uncertainty in this value can be found from

$$\frac{(\max - \min)}{2}$$

Do this by writing the appropriate formula into the spreadsheet.

Conclusion and evaluation

Compare your value of the refractive index with the value obtained from a databook or web-based database.

Is your value acceptably close to this?

Possible problems are:

- Not positioning the pins accurately.
- The sides of the block are uneven.
- The block is not made from the same material as the block giving the database value.
- The air does not have refractive index of exactly 1.

Use your results to decide if any of these factors (or others) affected your results and suggest ways to eliminate the problem. If you have time, try the experiment again incorporating your improvements.

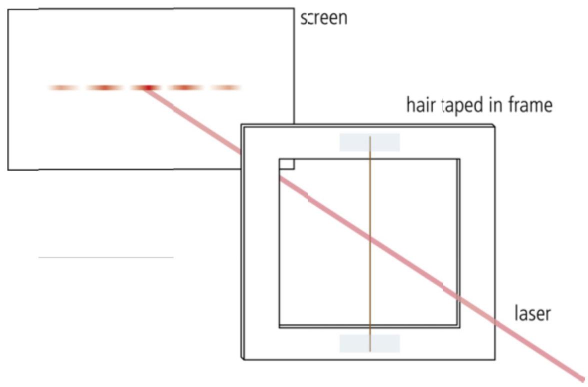
C.3 Wave phenomena

Interference of light using a hair keeping the relative size

Lab Worksheet

Introduction

Light passing through two parallel slits will diffract at each slit. If the slits are close to one another the light will interfere in the region where the two diffracted light beams overlap. In the classic Young's slits experiment sunlight was used but since the slits are very narrow it's not easy to see the resulting fringes. Using a laser makes it much easier to see the result but you must be careful not to look into the beam. If your school has ready-made parallel slits then you can use them but if you don't you can use a hair instead.

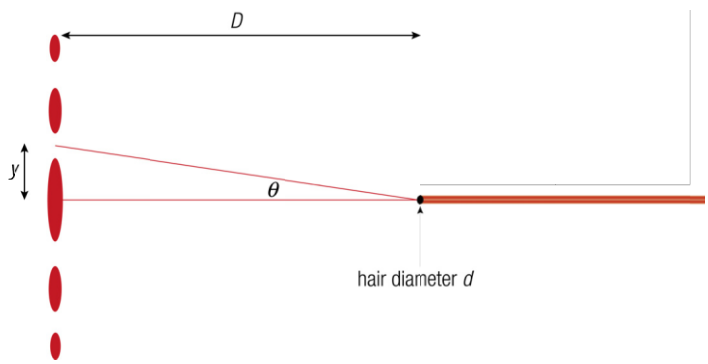


Apparatus

- a low-powered laser. The sort used as a laser pointer will do.
- a mounted hair. Find a long, dark-coloured hair and tape it in a cardboard frame as shown in the diagram.

Theory

The angle, θ, between the central maximum and the first minimum is given by the equation sin θ = the separation of the slits or, if using a hair, the diameter of the hair.



Method

Mount the hair within a cardboard frame and using a clamp stand, or blu tack and books, arrange the hair and laser so that the laser can be diffracted by the hair and continue to a wall about 4 m away. To make the pattern clearer, a piece of white paper could be stuck on the wall. Line up the laser and slit so that a horizontal line of dots is seen on the screen. Use a ruler to measure the distance between the first minima on either side of the central maximum (this is $2y$). Also measure the distance from the hair to the screen (D). You could repeat the experiment with hairs of different thickness to get a range of values.

Processing data

Find the wavelength of the laser then use, your data to find the thickness of the hair:

$$\sin\theta = \frac{y}{D} = \frac{\lambda}{d}$$

$$d = \frac{\lambda D}{y}$$

You will also need to find the uncertainty in your final value.

This is best done by summing the fractional uncertainties.

Fractional uncertainty in *d*, Δd:

$$\frac{\Delta d}{d} = \frac{\Delta\lambda}{\lambda} = \frac{\Delta D}{D} = \frac{\Delta y}{y}$$

Conclusion and evaluation

Measure the thickness of the hair with a micrometer and compare the value with the one obtained from the experiment. Is the value obtained from the interference experiment close enough to the measured value?

Possible problems are:

- the hair is uneven
- the measurement of the diffraction pattern was inaccurate
- the measurement of the distance to the screen was inaccurate
- the laser wavelength was inaccurate
- the diffraction pattern was unclear.

What do you think was the weakness in your method?

How could you improve the method to achieve a result that is closer to the measured value?

Try your modified method to see if it improves your result.

Simulation

To develop a clearer understanding of diffraction and interference you could use Paul Falstad's Ripple tank® http://www.falstad.com/ripple/.