جامعة الملك سعود
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تجارب مختبر الفيزياء الموجية

- 395 فيز -

Contents

Abbe Refractometer

1 Objective

- To find refractive index of the given liquid samples and find Molar refraction and specific refraction.

2 Prelab Questions

1- Define refractive index (n), density (d), specific refraction (R) and molar refraction (R_M).

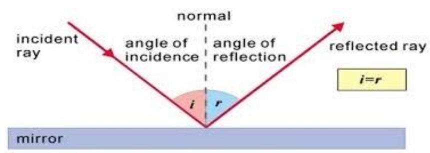
2- Find the refractive index (n) and the density (d) of water and sucrose solutions in deferent concentration (70%, 60%, 50%, 40%, 30%, 20%, 10%) at room temperature.

3 Principles

The Abbe refractometer, named after its inventor Ernst Abbe (1840-1905), was the first laboratory instrument for the precise determination of the refractive index of liquids. The measuring principle of an Abbe refractometeris based on the principle of total reflection. Abbe refractometers are used for measuring liquids. The reference media glasses (prisms) can be selected with high refractive indices. The light froma radiation source is reflected by a mirror and hits a double prism. A few drops of the sample are placed between this so-called Abbe double prism. The incident light beams pass through the double prism and sample only if their angles of incidence at the interface are less than the critical angle of total reflection. A microscope and a mirror with a suitable mechanism areused to determine the light / dark boundary line (shadow line).

Reflection of light

Reflection of Light is the process of sending back the **light** rays which falls on the surface of an object. The image formed due to **reflection** of anobject on a plane mirror is at different places



Reflection is the change in the direction of wave passing from one medium to other medium. Some part of the rays reflects at the same angle (α) and some refract at different angle (β)

Snell's Law

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant, for the light of a given colour and for the given pair of media. The refractive angle is determined by Snell's law

$$n_1 \, Sin\, \alpha = n_2\, Sin\beta$$

n_1 is refractive index of medium 1

$n_($ is refractive index of medium 2

$$\frac{\text{Sin i}}{Sin\ r} = n = \frac{velocity\ of\ light\ in\ 1st\ medium}{velocity\ of\ lightt\ in\ 2nd\ medium}$$

Abbe's Refractometer

The Abbe instrument is the most convenient and widely used refractometer, Fig(1) shows a schematic diagram of its optical system. The sample is contained as a thin layer (~0.1mm) between two prisms. The upper prism is firmly mounted on a bearing that allows its rotation by means of the side arm shown in dotted lines. The lower prism is hinged to the upper to permit separation for cleaning and for introduction of the sample. The lower prism face is rough-ground: when light is reflected into the prism, this surface effectively becomes the source for an infinite number of rays that pass through the sample at all angels. The radiation is refracted at the interface of the sample and the smooth-ground face of the upper prism. After this it passes into the fixed telescope. Two Amici prisms that can be rotated with respect to another serve to collect the divergent critical angle rays of different colors into a single white beam, that corresponds in path to that of the sodium D ray. The eyepiece of the telescope is provided with crosshairs: in making a measurement, the prism angle is changed until the light-dark interface just coincides with the crosshairs. The position of the prism is then established from the fixed scale (which is normally graduates in units of n_D). Thermosetting is accomplished by circulation of water through the jackets surrounding the prism.

The Abbe refractometer is very popular and owes its popularity to its convenience, its wide range (n_D = 1.3 to 1.7), and to the minimal sample is needed. The accuracy of the instrument is about ±0.0002; its precision is half this figure. The most serious error in the Abbe instrument is caused by the fact that the nearly glazing rays are cut off by the arrangement of to prisms; the boundary is thus less sharp than is desirable. A *precision* Abbe refractometer, that diminishes the uncertainties of the ordinary instrument by a factor of about three, is also available; the improvement in accuracy is obtained by replacing the compensator with a monochromatic source and by using larger and more precise prism mounts. The former provides a much sharper critical boundary, and the latter allows a more accurate determination of the prism position.

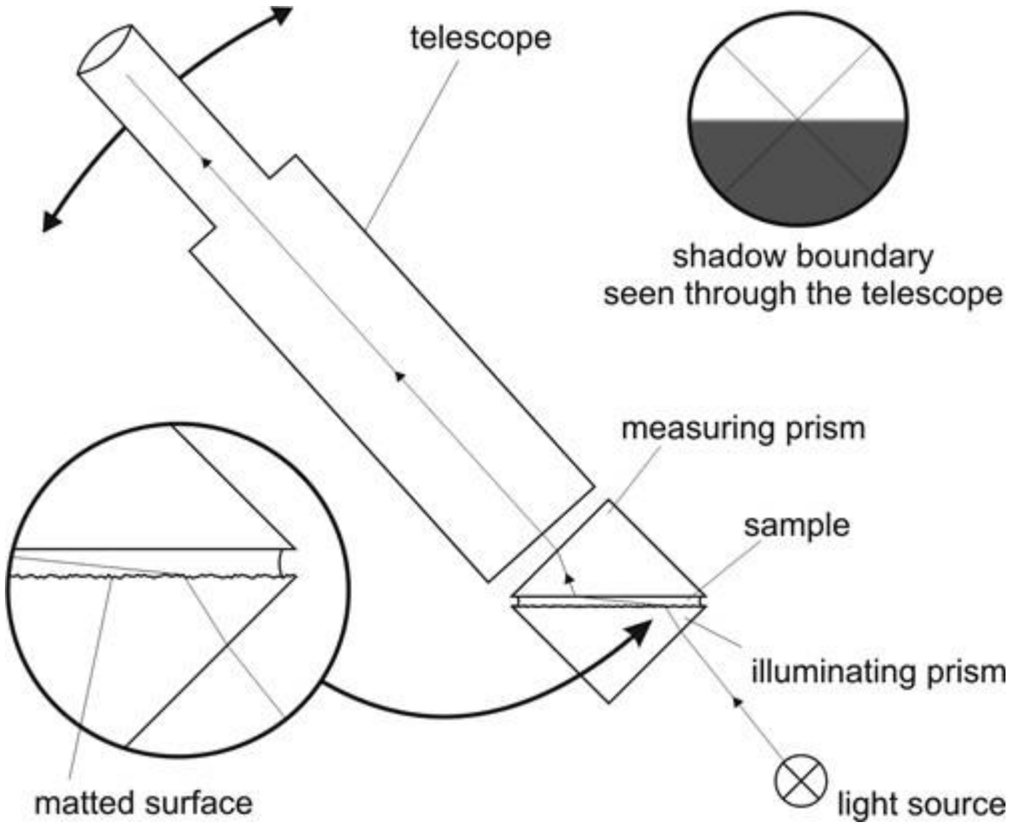


Figure-1: Light entering the illuminating prism producing dark and bright regions in the field of view

Measurement of refractive index

The refractive index of a substance is ordinarily determined by measuring the change in direction of colliminated radiation as it passes from one medium to another.

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\sin \theta_1}{\sin \theta_2} \qquad (1)$$

Where v_1 is the velocity of propagation in the less dense medium M_1 and v_2 is the velocity in medium M_2; n_1 and n_2 are the corresponding refractive indices and θ_1 and θ_2 are the angles of incidence and refraction, respectively Fig 2.

When M_1 is a vacuum, n_1 is unity because v_1 becomes equal to c in equation (1).

Thus,

$$n_2 = n_{vac} = \frac{c}{v_2} = \frac{\sin \theta_1}{\sin \theta_2} \qquad (2)$$

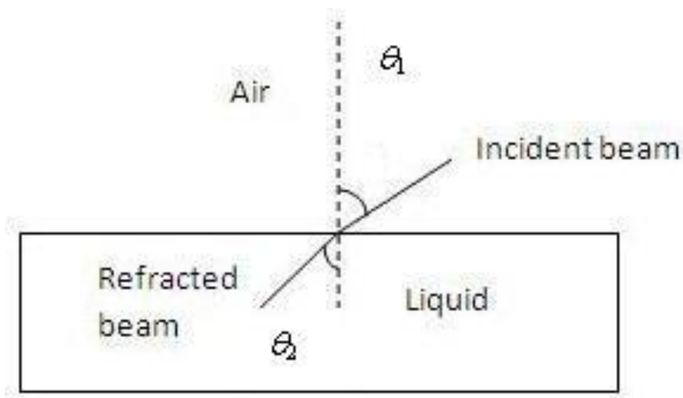


Fig. 2

Where n_{vac} is the absolute refractive index of M_2. Thus n_{vac} can be obtained by measuring the two angles θ_1 and θ_2.

Factors affecting refractive index

Various factors that affect refractive index measurement are

1.Temperature

Temperature influences the refractive index of a medium primarily because of the accompanying change in density. For many liquids, the temperature coefficient lies in the range of -4 to -6 $\times 10^{-4}$ deg^{-1}. Water is an important exception, with a coefficient of about -1 $\times 10^{-4}$ deg^{-1}.

2. Wavelength of light used

The refractive index of a transparent medium gradually decreases with increasing wavelength; this effect is referred to as normal dispersion. In the vicinity of absorption bands, rapid changes in refractive index occur; here the dispersion is anomalous.

3. Pressure

The refractive index of a substance increases with pressure because of the accompanying rise in density. The effect is most pronounced in gases, where the change in n amounts to about $3x10^{-4}$ per atmosphere; the figure is less by a factor of 10 for liquids, and it is yet smaller for solids.

4 Apparatus

Abbe's refractometer.

5 Experimental Steps

1. Clean the surface of prism first with alcohol and then with acetone using cotton and allow it to dry.
2. Using a dropper put 2-3 drops of given liquid b/w prisms and press them together
3. Allow the light to fall on mirror.
4. Adjust the mirror to reflect maximum light into the prism box
5. Rotate the prism box by moving lever until the boundary b/w shaded and bright parts appear in the field of view.
6. If a band of colors appear in the light shade boundary make it sharp by rotating the compensator.

7. Adjust the lever so that light shade boundary passes exactly through the centre of cross wire

8. Read the refractive index directly on the scale

Figure 2. Refractive index values as read on the scale

9. Take 3 set of readings and find the average of all the readings.

10. The refractive index of water is 1.3333

OBSERVATIONS:

Room temp. =........................... degrees

Sr.#	Liquid	Refractive index

Specific refraction, R = $(n^2 -1)/(n^2 + 2) \times 1/d$

Molar refraction, R_M= R ×M (molecular mass of liquid)

Refractive index of some common liquid

Variation of refractive index with wavelength
6. To study the effect of wavelength of light on refractive index, we have used blue (420nm), yellow
(590nm) and red (630nm) LED lights obtained from a solid state lamp. For castor oil the value of the
refractive index obtained is tabulated in Table-2.

Table-2

Liquid	Refractive index		
	420 nm (Blue)	630nm (Red)	590 nm (Yellow)
Castor oil	1.475	1.476	1.475

Refractive index of castor oil for blue, yellow and red lights

It may be noted that the value of refractive indices obtained for different colours of light are the same,
indicating the inability of the model to differentiate wavelengths.

Table-1

Liquid	Refractive index	
	Expt.	Standard
Castor oil	1.474	1.4470 -1.4810
Milk	1.424	1.3500-1.4500
Water	1.325	1.3330
Honey	1.472	1.4800-1.5000
Sunflower oil	1.458	1.4600
Sugar syrup (50%)	1.448	1.4200
Dettol cream	1.359	NA

Refractive index of some common liquids

6 Post lab questions

4g sugar cube (sucrose: $C_{12}H_{22}O_{11}$) is dissolved in a 350 ml teacup filled with hot water. What is the molarity of the sugar solution.

7 Reference

[1] http://www2.ups.edu/faculty/hanson/labtechniques/refractometry/theory.htm
[2] G H Meeteen, Refractive index measurement, Schluberger Cambridge Research, CRC press LLC, 1999
[3] http://www.refractometer.pl/refractometer-history

Diffraction Grating

1 Objective

Calculating wavelengths using a Diffraction Grating.

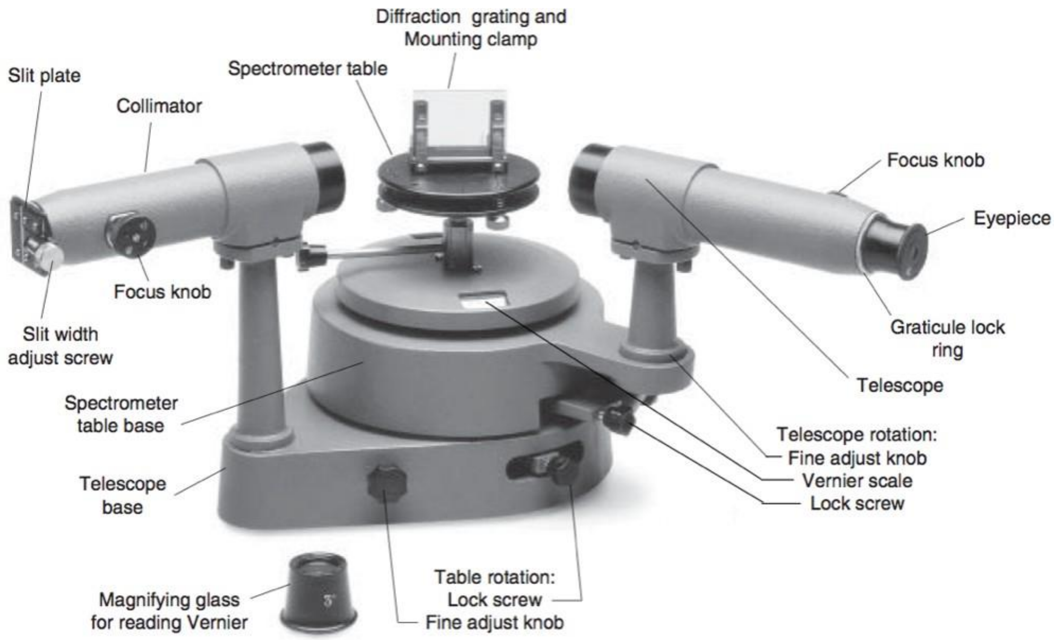
2 Prelab Questions

1. Briefly explain the phenomenon of light diffraction.
2. Write a short description of a Diffraction Grating and explain how it diffracts light.
3. By using an illustration, compare between the spectra obtained from a diffraction grating and from a prism.

3 Principles

Light from a light source with a discrete spectrum is passed through a collimator. The light is then diffracted by a grating and studied using a telescope.

4 Apparatus



5 Precautions

1. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.
2. The Diffraction Grating is a delicate component. Do not scratch the surface or touch it with your fingers.
3. Stray light can obscure the images seen through the telescope. Preform the experiment in pitch-black darkness.

6 Experimental Steps

6.1 Calibration:

1. Align the collimator and the telescope so that the vertical cross-hairs (seen through the telescope) are aligned with the slit (seen through the collimator).

2. Loosen the spectrometer table lock-screw. Align the vernier scale on the spec- trometer table so that it is collinear with the optical axes of the telescope and collimator. Tighten the lock-screw.
3. Use the spectrometer table fine adjust knob to make sure that they are perfectly collinear.

6.2 Experiment:

1. Place the vertical cross-hair directly on top the slit and record the angle of zero diffraction θ_0.
2. Rotate the telescope towards the right hand side to find the first bright slit image (colour), continue rotating it across the rest of the colours until the same slit image (colour) appears again. Observe how the spectrum repeats itself, growing fainter the farther you are from the angle of zero diffraction.
3. Go back to the first slit image (colour). Carefully align the vertical cross-hair with the image and measure the angle of diffraction $\theta_{\boldsymbol{R}}$. Which order of diffraction n are you observing?
4. Now rotate the telescope towards the left hand side, past the zero diffraction angle,to find an identical slit image (same colour).
5. Carefully align the vertical cross-hair with the image and measure the angle of diffraction $\theta_{\boldsymbol{L}}$.
6. Repeat steps [3-5], recording the angles for each colour in the first order of diffraction.
7. Now move on to the second order of diffraction. It should be slightly fainter than the first. Repeat the steps [3-5], recording the angles for each colour in the second order of diffraction.

7 Evaluation

1. Calculate the angle of diffraction for the right hand side $\Delta\theta_{\boldsymbol{R}}$ and for the left handside $\Delta\theta_{\boldsymbol{L}}$
2. Using the diffraction grating equation, calculate the wavelength of each colour:

$$\lambda = \frac{a \sin\theta}{n} \tag{1}$$

8 Postlab Questions:

1. Explain the reason behind the observed correlation between: the higher the order of diffraction *n*, the fainter the light appears.
2. Name a few real-life examples exhibiting the phenomenon of light diffraction.
3. If a monochromatic light source was used instead of the one used in this experiment, what do you expect to observe?
4. In a diffraction grating experiment, a certain colour emerges at an angle of 15°in the first order. At what angle would this same colour emerge if the same light source and grating was used?

Fresnel’s Biprism

1 Objective

- Determination of the wavelength of light by interference with Fresnel’s biprism.

2 Prelab Questions

1. Give a general explanation of the phenomenon of light interference: constructive interference, destructive interference and what is meant by bright/dark fringes.
2. What is meant by a light source with a discrete spectrum?
3. What are the main differences between a laser source and an incandescent light source?

3 Principles

Fresnel biprism is used to divide the wavefront of a monochromatic, coherent beam oflight producing an interference pattern. The wavelength of the light is determined.

4 Apparatus

- Fresnel biprism.
- Lenses (f = 20 mm and 300 mm).
- Lens mounts.
- Swinging arm and slide mounts.
- Optical bench.
- Laser, He-Ne 1.0 mW, 220 V AC.
- Measuring tape, 200 cm.

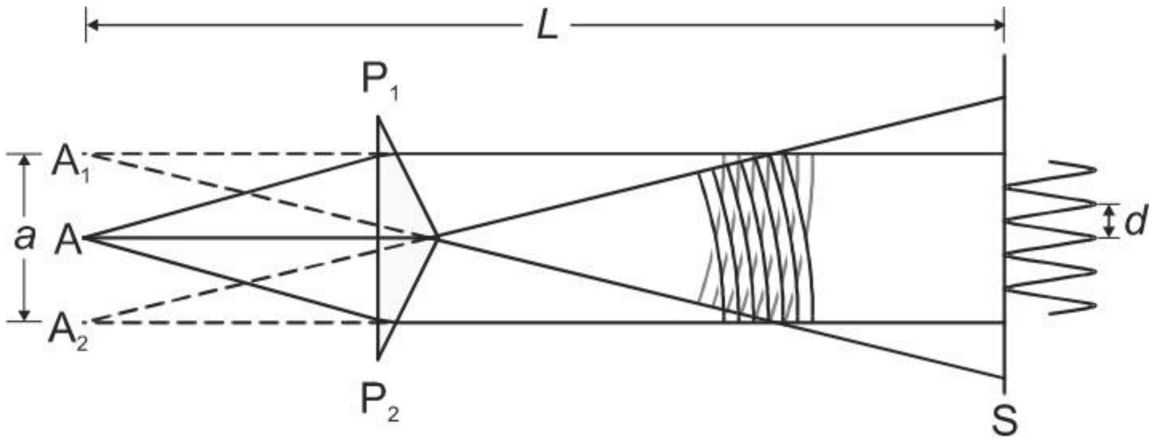


Fig 1. Schematic representation of the beam path at Fresnels biprism:

A: Light source (He-Ne laser).
A_1 and A_2: Virtual light sources.S: Screen/wall.
a: Distance between the two virtual light sources.
d: Distance between two neighbouring intensity maxima or minima.
P_1 and P_2: Prism halves.
L: Separation between laser and screen/wall.

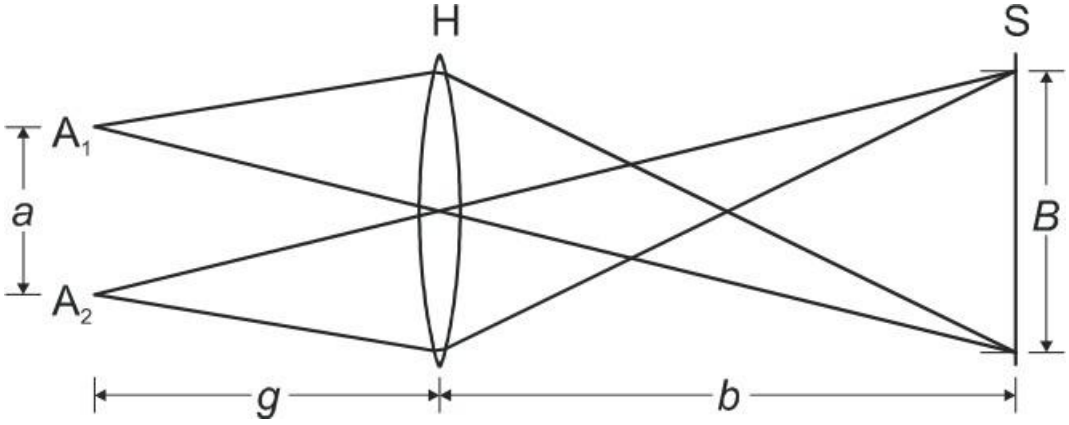


Fig 2. Schematic representation of the image of the two virtual light sources:

H: Imaging lens H.
A_1 and A_2: Virtual light sources.S: Screen/wall.
a: Distance between the two virtual light sources.
B: Distance between the image of two virtual light sources on the screen. g: Distance between the virtual sources and the lens H (object distance). b: Distance between the lens H and the screen S.

5 Precautions

1. Laser light is dangerous and can potentially cause visual impairment. Never look directly into any laser beam. Prolonged exposure will cause flash-blindness, afterimages and glare which will reduce or cause complete loss of visibility in the central field of vision.
2. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.
3. Stray light can obscure the images seen on the screen. Preform the experiment in pitch-black darkness.

6 Experimental Steps

6.1 Part 1: Interference Pattern (Fig. 1):

1. In front of you, the He-Ne laser is mounted at the 2 cm mark.
2. Mount the lens (f = 20 mm) at the 23.3 cm mark. This lens spreads the laser beam slightly (widens it).
3. Mount the biprism at the 45 cm mark, with its tip facing the laser. Use your finger to determine where the biprism's tip is.
4. You should be able to see an interference pattern on the wall.
5. Using a vernier scale, measure the separation D between five maxima/minima.
6. Repeat step 5 three times, measuring D_1, D_2 and D_3.
7. Measure the distance L between the laser and the screen/wall.

6.2 Part 2: Virtual Source Separation (Fig. 2):

1. Mount the lens (f = 300 mm) at ≈60 cm mark. You should be able to see two separate light points.
2. Using a vernier scale, find the distance B between the two light points.
3. Measure the distance b between the lens H and the screen S.

7 Evaluation

1. Calculate the separation d between two successive maxima/minima:

$$d_n = \frac{D_n}{5} \tag{1}$$

   Where n = 1, 2 and 3.

2. Find the average d_{avg} of d_n.

3. Calculate the distance g between the virtual sources and the lens H (object distance) using the imaging equation:

$$g = \frac{fg}{b-f} \tag{2}$$

Where $f = 300$ mm.

4. Calculate the distance a between the virtual light sources:

$$a = \frac{Bg}{b} \tag{3}$$

5. Find the wavelength λ using:

$$\lambda = \frac{d_{avg}a}{L} \tag{4}$$

6. Calculate the error percentage.

8 Postlab Questions

1. What is meant by the virtual source in Fresnels Biprism experiment?
2. Using the experimental sketch above, explain how such a source arises.
3. You can find the value of g using an equation other than the imaging equation.Write the expression of that equation, explaining how you obtained it.

Lloyd's Mirror

1 Objective

- Understand the nature of sound-waves.
- Calculate the frequency of ultrasonic sound-waves by Lloyd's Mirror Interference.

2 Prelab Questions

1. What is meant by an ultrasonic sound-wave and what is the difference between a sound-wave and an electromagnetic wave?
2. Do you expect sound-waves to behave similarly to electromagnetic waves in terms of interference/diffraction/reflection/refraction despite the difference in their inherent characteristics and origins?
3. What are the conditions for constructive interference based on the difference in path length Δ?
4. Consider the graph below:

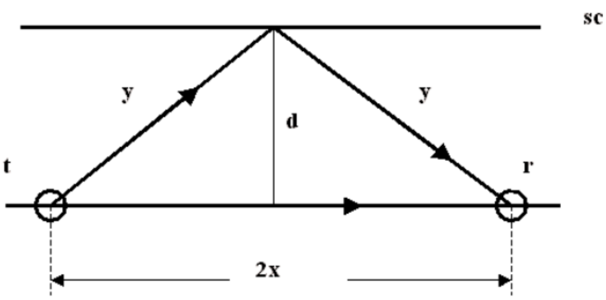


Fig 1. Schematic representation of the interference setup showing the path difference $\Delta = 2y$.

t: Transmitter (source).
r: Receiver (where the interference occurs).sc:
Screen (reflective surface).

Using the graph, derive the following constructive interference equation $\Delta = n\lambda = 2(\sqrt{d^2 + x^2} - x)$

3 Principles

A packet of ultrasonic sound-waves is emitted from a fixed ultrasonic transmitter. Partof the packet strikes a metal screen positioned parallel to the line of propagation betweenthe transmitter and the receiver, and is reflected in the direction of the receiver. The two packets of radiation arrive at the receiver and interfere with each other. Whenthe reflector is moved backwards/forwards, the difference in the path lengths of thetwo packets changes. According to this difference, either constructive or destructive interference occurs.

4 Apparatus

- Ultrasonic production unit.
- Ultrasonic transmitter and receiver.
- Digital multimeter.

- Optical bench.
- Various mounts.
- Metal screen.
- Swinging arm and sliding device.
- Measuring tape.
- Cords.

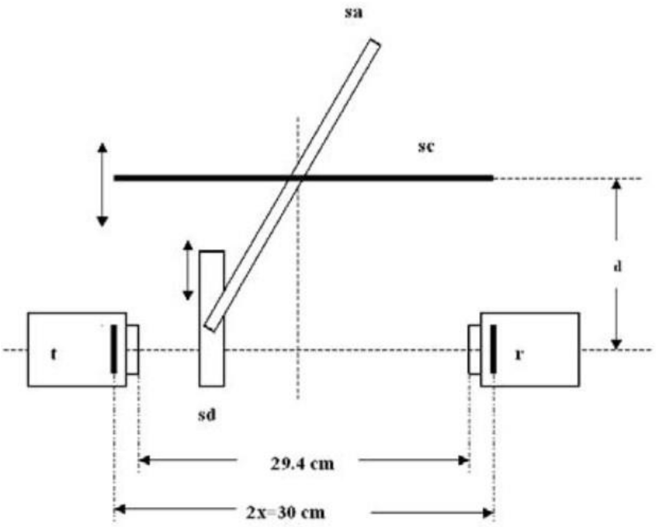


Fig 2. Experimental set-up of Lloyd's Mirror apparatus:

t: Transmitter.
r: Receiver.
sd: Sliding device.
sa: Swinging arm.
sc: Screen.

5 Precautions

1. Make sure to mount the transmitter and receiver at the same heights.
2. Orient the two devices so that their centres are concordant and parallel to the optical bench.

3. Make sure that the reflector screen is parallel to the optical bench and reset the scale.
4. If the *OVL* diode lights up, reduce the transmitter amplitude or the input amplification.

6 Experimental Steps

1. Mount the ultrasonic transmitter and the ultrasonic receiver in their slide mounts and set them at a distance of 29.4 cm. Keep in mind that the active parts ofthe ultrasonic elements are actually behind the protective grids, which makes the effective distance $2x$ between the two devices 30 cm.
2. Set the reflector screen at a distance of 2 cm from the middle axis which connects the transmitter and receiver, not the optical bench.
3. Connect the transmitter to the TR1 diode socket of the ultrasonic unit and set itto operate under continuous mode Con.
4. Connect the receiver to the left BNC socket.
5. Connect the receiver to the analog output of the digital multimeter.
6. Use the sliding device to move the screen backwards/forwards and locate the first maximum of the interference pattern, where $n = 1$. Record the voltage V fromthe multimeter and the distance d.
7. Move the screen away from the optical bench in steps of $\Delta d = 0.5$ to 1 mm, reading off the voltage and distance.

7 Evaluation

1. Plot a graph between the voltage V and the distance d. What does your graph represent?
2. Using your graph, read off the distances d that correspond to $n = 1, 2, 3...$ etc.
3. Using the equation below, calculate the wavelengths of the ultrasonic waves:

$$n\lambda = 2(\sqrt{d^2 + x^2} - x) \quad (1)$$

For n = 1, 2, 3... etc.

4. Find the average wavelength λ_{avg}.
5. Using the average wavelength, calculate the frequency f of the ultrasonic waves.

8 Postlab Questions

1. Briefly describe the process by which sound-waves undergo refraction and reflection.
2. What is the speed of sound and its relation to temperature?
3. Describe the reflective surface you used in this experiment. Would a regular mirror do the same job?

Melde's Experiment

1 Objective

- Generating standing, circularly polarised thread waves for various tension forces F, thread lengths s and thread densities m^*.
- Determining the phase velocity c of thread waves as a function of the tension force F, the thread length s and thread density m^*.

2 Prelab Questions

1. What are standing waves?
2. How do standing waves form and what are the conditions for their formation?

3 Principles

An elastically tensioned thread is attached to a mechanical vibrator and weighted fromthe other end is allowed to vibrate. Standing waves form and are analysed.

4 Apparatus

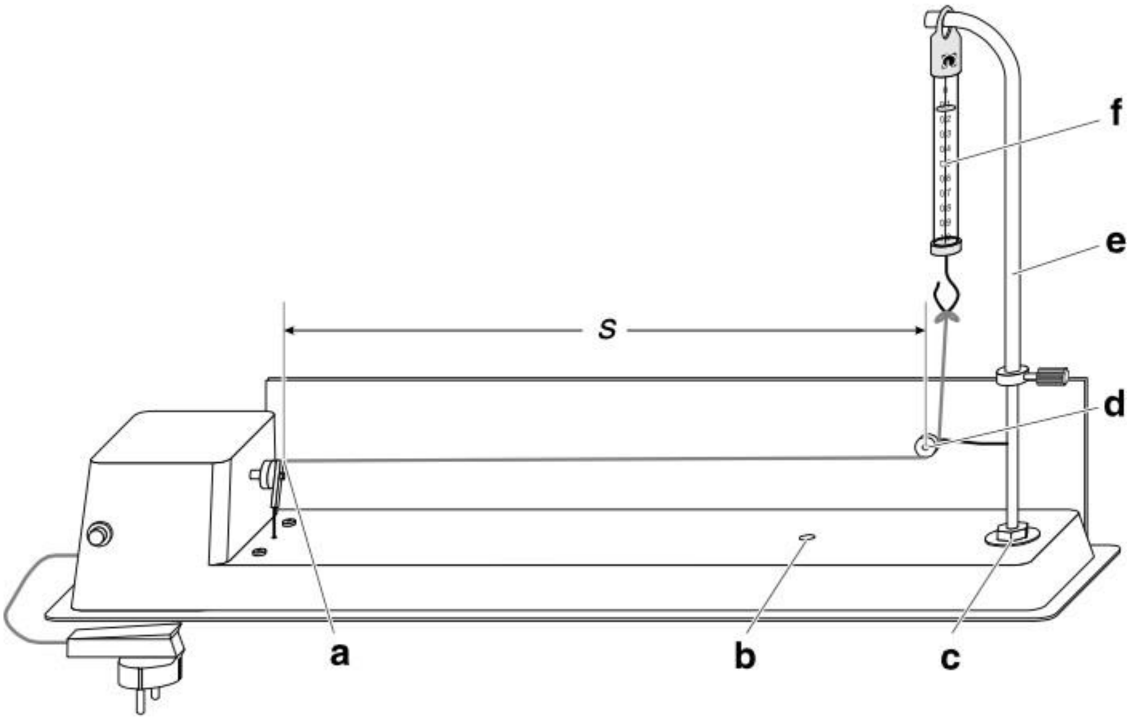


Fig. 1: Schematic representation of Melde’s setup: a: Cam.

b: Mounting point for thread length s = 0.35 m.

c: Mounting point for thread length s = 0.48 m.

d: Deflection pulley.

e: Holding arm.

f: Dynamometer.

5 Precautions

1. When measuring the length of the thread s, note that the actual length (effective) of the string is measured between cam **a** and the centre of the deflection pulley **d**.

2. Be careful not to overload the string and cause it to snap violently.

6 Experimental Steps

1. Measure the distance s between cam **a** and the centre of the deflection pulley **d**.This is your effective thread length.

2. Switch on the motor of the apparatus.

3. On the holding arm **e**, loosen the adjusting screw and vary the force F by changing the height of the holding arm until a standing wave of maximum amplitude with the wavelength $\lambda = 2s$ is formed. You should be able to see one oscillation antinode, in this case $n = 1$.

4. Read off the corresponding force F_1 and write this value in the experiment log.

5. Use the stroboscope to determine the excitation frequency f. Set the dial to the maximum frequency and slowly reduce the frequency until a simple standing si- nusoidal wave becomes visible. You should be able to see a perfect sine wave, standing still clearly.

6. Repeat Steps [3-5] for different values of F_n, f and n, until $n = 6$.

7. Switch off the motor.

8. Measure the mass m_0 of the thread.

9. Measure the entire length of the thread s_0.

7 Evaluation

1. Calculate the linear mass density m^* of the thread.

$$m^* = \frac{m}{s} \tag{1}$$

2. Calculate the phase velocity (propagation speed) c_F of the thread for each F.

$$c_F = \sqrt{F/m^*} \tag{2}$$

3. Calculate the wavelength λ for each mode.

$$\lambda_n = \frac{2s}{n} \tag{3}$$

4. Using the results from Eq (3), calculate the phase velocity (propagation speed) c.

$$c = \lambda f \tag{4}$$

5. Plot c vs. c_F and calculate the slope. It should be ≈1.
6. Explain why the slope should be ≈1, and calculate the error percentage in your experiment.

8 Postlab Questions

1. What is the difference between standing waves on a string and standing waves in air columns?
2. What are the natrual frequencies for a one dimensional string, with one free end and one fixed end, of length s and linear mass density $m*$ under tension F?

Newton’s Rings

1 Objective

Calculating the wavelength of the D-line in a sodium lamp.

2 Prelab Questions

1. Give a general explanation of the phenomenon of light interference: constructive interference, destructive interference and what is meant by bright/dark fringes.
2. Briefly explain the phenomenon of thin-film interference.

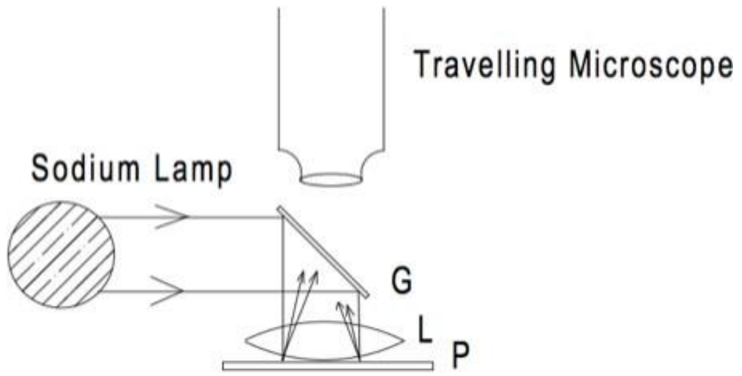
3 Principles

Light from a light source with a discrete spectrum is directed towards a reflective plate.The light is then passed through a lens and allowed to interfere.

4 Apparatus

- Travelling microscope.
- Sodium lamp.
- Plano-convex lens [L] with a focal length $f = 10$cm.

- Planar plate [P].
- Sheet of glass [G] placed at an angle so that it reflects light towards the lens [L] and plate [P].



5 Precautions

1. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.
2. The lens, glass sheet and the planar plate are delicate components, thoroughlyclean them and make sure not to scratch their surface.
3. Stray light can obscure the images seen through the microscope. Preform the experiment in pitch-black darkness.

6 Experimental Steps

1. Switch on the lamp and wait for a while until the light it emits regulates and turns yellow.
2. Using your naked eye, notice the formation of concentric rings in the space between the lens and the planar plate.

3. Place the travelling microscope directly above the glass sheet. Look through the microscope and adjust its position by moving it upwards or downwards until therings come into focus. The rings are referred to as fringes and they form due tothe interference of light.

4. Search for the centre of the rings by moving the microscope rightwards or leftwards. Upon finding the centre, place the crosshairs directly in the middle

5. Notice that the crosshairs divide the concentric circles in half. There is a right-hand side and a left-hand side.

6. Move the microscope towards the right-hand side, and align the vertical crosshair with the outer edge of the tenth fringe (tenth circle). Record the reading of the microscope d_r and the fringe number n.

7. Now move the microscope towards the left, and align it with the outer edge of the ninth fringe (ninth circle). Notice that you are still in the right-hand side.

8. Repeat steps [6 and 7] for each fringe, crossing the centre and moving on to the left-hand side.

9. Once you crossed towards the left-hand side, start recording d_l as well as the fringe number n, until you reach the outer edge of the tenth fringe on the left-hand side.

7 Evaluation

1. Calculate the diameter of the fringes using:

$$D = |d_r - d_l| \tag{1}$$

   And then square it to obtain D^2.

2. Plot a graph between the fringe number n and the square of the diameter D^2.

3. Using the slope of the graph, calculate the wavelength of the D-line, given:

$$\lambda = \frac{1}{4R} \times \frac{D^2}{n} \tag{2}$$

   Where $R = 50$cm.

8 Postlab Questions

1. Explain the reason behind the concentricity of the interference pattern you ob- served in the experiment.

2. Colour shifting ink used in modern banknotes as a measure against counterfeit notes displays two distinct colours depending on the angle of viewing. Using theconcept of thin-film interference, can you explain how this effect is achieved?

Photometric Law of Distance

1 Objective

- The luminous intensity I emitted by a punctual source is determined as a function of distance from the source.
- The photometric law of distance is verified by plotting illuminance as a function of the reciprocal value of the square of the distance.

2 Prelab Questions

1. What is the difference between radiometry and photometry?
2. What is a *solid angle*? State the solid angle of a sphere.
3. State the Photometric Law of Distance and explain it.
4. Define the following terms: luminous flux, luminous intensity, illuminance, luminance and luminous existance, stating their respective laws and SI units.

3 Principles

The luminous intensity emitted by a punctual source is determined as a function of distance.

4 Apparatus

- Luxmeter.
- Luxmeter probe.
- Optical profile bench.
- Several slide mounts.
- Filament lamp 6 V/5 A.
- Universal clamp.
- Power supply.

5 Precautions

1. The input voltage for the lamp is 6 V.
2. The luxmeter must be calibrated before actually carrying out measurements. Possible background luminance must be determined with the lamp switched off andmust be taken into account during evaluation.
3. Notice that the luxmeter probe is offset from the centre of the clamp.

6 Experimental Steps

1. Switch on the luxmeter and measure the background illuminance E_0.
2. Set the separation r between the probe and lamp to 55 cm.
3. Switch on the lamp and measure the illuminance E.
4. Decreasing the separation in steps of 5cm, record E until you reach a separationof r = 25 cm.

7 Evaluation

1. Calculate r^2 and $1/r^2$
2. Plot E vs. r^2, confirming the Photometric Law of Distance.
3. Plot E vs. $1/r^2$ and find the slope.
4. Using the slope, calculate the luminous intensity I of the lamp, knowing that:

$$E = \frac{I}{r^2} \tag{1}$$

8 Postlab Questions

1. What is the difference between photopic and scotopic vision?
2. A surface oriented perpendicularly is positioned 2 m away from a lightbulb emitting 100 W of radiant flux.
   (a) Calculate the irradiance E_e at the surface.
   (b) If all 100 W is emitted from a red bulb at λ = 650 nm, calculate the illumi-nance E_v at the surface.

   Hint: use the following equation: $photometricunit = K(\lambda) \times radiometricunit$. Where $K(\lambda)$ is the luminous efficacy given by: $K(\lambda) = 685V(\lambda)$ and $V(\lambda)$ is the luminous efficiency obtained from a CIE luminous efficiency curve.

Polarimetry

1 Objective

Study the phenomenon of optical rotation caused by different concentrations of glucose solutions.

2 Prelab Questions

1. What is light polarisation?
2. Provide a brief explanation of optical activity, listing examples of optically activemedia.
3. What is meant by *chiral* molecules?

3 Principles

Light from a light source with a discrete spectrum is directed towards a polariser. The light is then passed through an optically active medium where its plane of polarisation undergoes rotation and is analysed.

4 Apparatus

- Polarimeter.

- Sugar (glucose).
- Distilled water.
- Scales.
- Various beakers.

5 Precautions

1. Be careful not to spill the solution onto the equipment.
2. The end plates (small glass inserts) for the cell (glass tube) are *very* sensitive and should be handled with care.

6 Experimental Steps

6.1 Measuring θ_0 for distilled water:

1. Carefully remove the cell from the Polarimeter.
2. Wash the cell carefully and dry it completely.
3. Fill the cell with distilled water, keeping it vertical, and cap it off using the end plate.
4. Carefully fit the tube back into the Polarimeter, and switch on the light source.
5. Look through the telescope and observe the resultant shape.
6. Rotate the analyser until you can observe a clear silhoutte to determine θ_0.

6.2 Preparing the glucose solution:

1. For a 60% concentration, weigh 60g of sugar using the scales.
2. Using a beaker, measure 100ml of distilled water.
3. Pour the sugar into the water and mix it very well, making sure that it dissolves completely.

6.3 Measuring θ for the 60% glucose solution:

1. Carefully remove the cell from the Polarimeter.
2. Empty the cell into the sink and fill it up with the 60% solution, capping it offusing the end plates.
3. Carefully fit the tube back into the Polarimeter.
4. Look through the telescope and observe the resultant shape.
5. Rotate the analyser until you can observe a clear silhoutte to determine θ_{60}.

6.4 Measuring θ for different concentrations:

1. Dilute the solution using the description in the subsection [6.5] below to obtain a different concentration.
2. Calculate θ for the new concentration using the same steps as above.
3. Repeat the process several times, calculating θ for a concentration of: 50%, 40%, 30%, 20% and 10%.

6.5 Diluting X% solutions:

1. Using the general equation of dilution, calculate V_f for the desired concentration:

$$V_i C_i = V_f C_f \tag{1}$$

   Where V_i and C_i are the initial volume and concentration respectively, and V_f and C_f are the final volume and desired concentration after dilution.

2. Using the value of V_f, subtract V_i to obtain ΔV.
3. Measure a quantity of distilled water equivalent to ΔV and pour that into your initial solution.
4. Mix the resultant mixture well to incorporate ΔV into V_i. The solution you created now is of concentration C_f.

7 Evaluation

1. Plot the concentration C onto the x-axis and the angle of rotation θ on the y-axis.
2. Using the slope of the resultant line, calculate the specific rotation of glucose using the equation:

$$S = \frac{10}{L} \times \frac{\theta}{C} \tag{2}$$

Where L is the length of the cell.

Spectrometer

1 Objective

- Calculating the diffractive index of the prism for each wavelength.
- Calculating the resolving power of the prism.

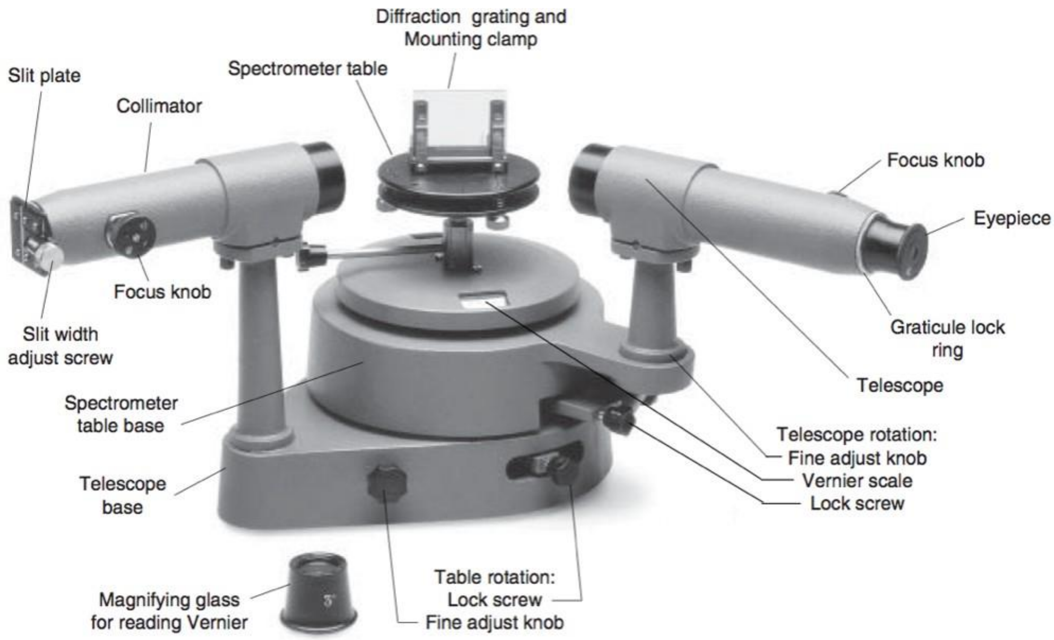
2 Prelab Questions

1. Briefly explain what is meant by the resolving power of the prism.
2. Write a short description of a prism and explain how it disperses light.
3. By using an illustration, compare between the spectra obtained from a diffraction grating and from a prism.

3 Principles

Light from a light source with a discrete spectrum is passed through a collimator. The light is then refracted by a prism and studied using a telescope.

4 Apparatus



5 Precautions

1. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.
2. The prism is a delicate component, do not scratch its surface.
3. Stray light can obscure the images seen through the telescope. Preform the experiment in pitch-black darkness.

6 Experimental Steps

Referring to the figure in [Section 4]:

1. The prism in front of you is mounted and fixed to the spectrometer table. Notice that the telescope is free to move in a semicircle about the prism.

2. With the prism in place, identify the direction of the refracted light. Rotate the telescope towards that general direction and look through the telescope. You should be able to see discrete spectral lines (colours). Lock the telescope in place using the telescope lock screw.

3. While looking through the telescope, slightly rotate the spectrometer table clockwise and notice how the spectrum behaves. The spectral lines under observation should move and change their positions. Now rotate the table counter clockwise and see how they return to their original position. Keep rotating the spectrome- ter table gently until you observe the spectral lines stopping momentarily before reversing the direction of their motion. The position at which the spectral lines reversed their motion is defined as the position of *minimum deviation*.

4. Lock the spectrometer table at the position of minimum deviation (screw it tightly and make sure that it does not move). Using the telescope fine adjust knob, movethe telescope to align the vertical cross hair with the first colour (red). Record the reading of the vernier scale θ.

5. Repeat step [4] for all the colours.

6. Carefully unscrew the prism and remove it without changing the position of the spectrometer table. Unlock the telescope and rotate it until you can see the image of the slit. Record the angle θ_0.

7. Place the prism on a white sheet of paper and calculate the internal angle of the prism A.

8. Measure the length of the prisms base b.

7 Evaluation

1. Calculate the angle of minimum deviation for each colour using:

$$D_m = |\theta - \theta_0| \tag{1}$$

2. Using the refractive index equation, calculate the refractive index for each colour:

$$n = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \tag{2}$$

3. Plot the wavelength versus the refractive index and use the slope to calculate the resolving power of the prism, given the resolving power equation:

$$R = b\frac{dn}{d\lambda} \tag{3}$$

8 Postlab Questions:

1. Explain why each colour has its own refractive index.
2. When immersing a colourful object in a glass of water (e.g a yellow pencil), the object appears broken but its colour does not change. By using the explanation in Question 1, explain why the object appears broken but its colour does not change.
3. If a monochromatic light source was used instead of the one used in this experiment, what do you expect to observe?

Young's Experiment

1 Objective

- Study the interference pattern caused by single slit diffraction.
- Study the interference pattern caused by double slit diffraction (Youngs Experiment).

2 Prelab Questions

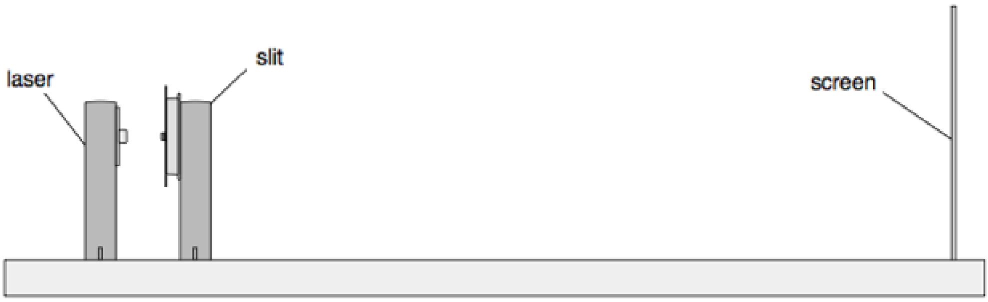
1. Give a general explanation of the phenomenon of light interference: constructive interference, destructive interference and what is meant by bright/dark fringes.
2. What are the main differences between a laser source and an incandescent light source?

3 Principles

Light from a diode laser is directed towards a slit disk. The light is then allowed to interfere and the interference pattern is studied.

4 Apparatus

- Diode laser.
- Precision optical bench.
- Single and double slit disks.
- Screen.
- Angular metric ruler.



5 Precautions

1. Laser light is dangerous and can potentially cause visual impairment. Never look directly into any laser beam. Prolonged exposure will cause flash-blindness, afterimages and glare which will reduce or cause complete loss of visibility in the central field of vision.
2. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.
3. Stray light can obscure the images seen on the screen. Preform the experiment in pitch-black darkness.

6 Experimental Steps

6.1 Single Slit Diffraction:

1. Place the angular metric rulers under the lamp to *"charge"* the glow-in-the-dark tips.

2. Arrange the equipment on an optical bench as seen above, placing the Single Slit Disk about 3cm in front of the laser. Keep in mind that the slit and laser are offset from the centre line of their holders.

3. Determine the distance D between the slit and the screen.

4. Switch on the laser and observe the resultant interference pattern on the screen.

5. Using the angular metric ruler, determine the separation between the first two minima $m = 1$ appearing on the screen.

6. Repeat step [5] for the second and third two minima $m = 2$ and $m = 3$ appearing on the screen.

7. Using a regular ruler, measure the distance between the tips of the angular metric ruler. Record the distance for the first, second and third minima as x_1, x_2 and x_3 respectively.

6.2 Double Slit Diffraction:

1. Place the angular metric rulers under the lamp to *"charge"* the glow-in-the-dark tips.

2. Exchange the Single Slit Disk with the Double Slit Disk, mounting it about 3cm in front of the laser. Keep in mind that the slit and laser are offset from the centre line of their holders.

3. Determine the distance D between the slit and the screen.

4. Switch on the laser and observe the resultant interference pattern on the screen.

5. Using the angular metric ruler, determine the separation between the first two maxima $m = 1$ appearing on the screen.

6. Repeat step [5] for the second and third two maxima $m = 2$ and $m = 3$ appearing on the screen.

7. Using a regular ruler, measure the distance between the tips of the angular metric ruler. Record the distance for the first, second and third minima as x_1, x_2 and x_3 respectively.

7 Evaluation

1. Calculate the distance y_m between the centre of the pattern and the m^{th} minima using the equation:

$$y_m = \frac{x_m}{2} \quad (1)$$

2. Calculate the wavelength of the laser using the equation:

$$\lambda = \frac{a y_m}{mD} \quad (2)$$

   Where a=0.08mm, denoting the width of the slit for the Single Slit Disk.

3. Find $\overline{\lambda}_{exp}$ and compare it to the theoretical value of the wavelength, obtained from the laser source itself.

4. Repeat the same calculations for the Double Slit Diffraction, where a=0.50mm, denoting the double slit separation for the Double Slit Disk.

8 Postlab Questions:

1. Calculate the wavelength of a laser light used to produce an interference patternon a screen 5.87m away if the distance between the central bright fringe and thefourth bright fringe is 8.21cm. The slit separation is 0.15mm.

2. If light did not exhibit a wave-like property, what would you expect to see on the screen? Draw an illustration of your expectations.

3. In the second part of the experiment, explain why you can see a set of smaller interference patterns enveloped within the bigger interference pattern.

Experiment Title

Student Name Group #

dd/mm/yyyy

1 Objective(s):

Give a brief summary of the purpose of the experiment.

2 Principle(s):

Write briefly the principle of the experiment.

3 Apparatus:

List all the tools and apparatus you used to perform the experiment

4 Data:

In this section you need to show your experimental results (data tables).

x (m)	V (V)
0.0031	0.015
0.0024	0.020
0.0056	0.045
0.0080	0.066

Table 1: Caption is important

5 Graphs:

Here you should include all the graphs you plotted from your data and write a caption for each one.

6 Data Analysis:

In this section, you need to explain the results you obtained in the data section, comment on the behavior of the data, and if there is any anomalies results, try to explain them. Also explain any calculations you performed in the tables.

7 Calculations:

In this section, you should illustrate your calculations and explain them briefly, Also you may need to include the calculation of the error percentage if required.

8 Conclusion:

Summarize your results and comment on them.