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- Object

To study the variation of T with L for a compound pendulum (Bar Pendulum) and then to determine the value of the acceleration due to gravity (g) in the laboratory

- Apparatus used

Bar Pendulum, Stop Watch, Knife Edges fixed to a rigid support and meter scale.

- Formula used

The value of g can be calculated with the help of the following formula:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Or

$$g = \frac{4\pi^2 L}{T^2}$$

L = Distance between centres of oscillation & suspension
T = Time period

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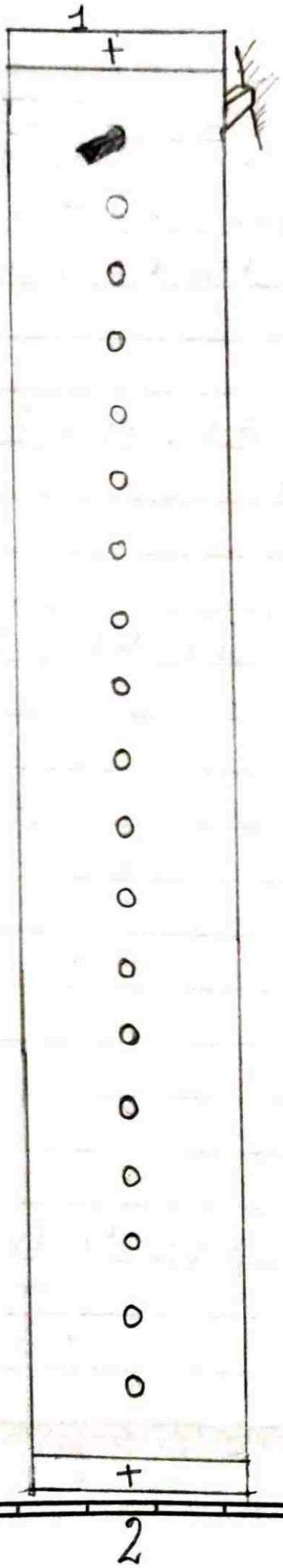
- Diagram



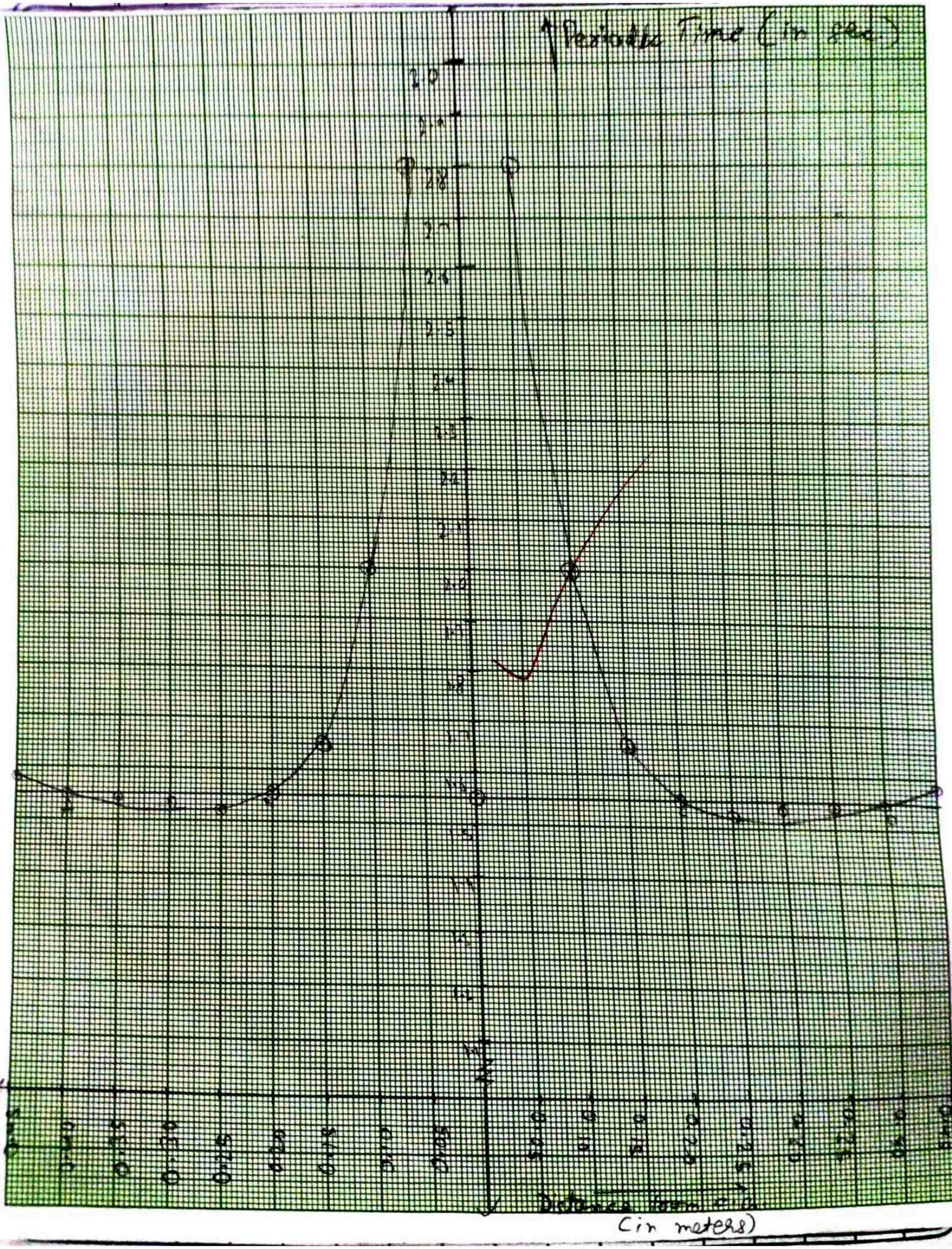

Bar Pendulum

## Description of Apparatus

A bar pendulum consists of a uniform rectangular bar about a meter long with holes drilled along its length at equal distances from each other. The centre lies on the straight line passing through the centre of gravity of the pendulum. A sharp knife edge is attached to some heavy frame provided with leveling screws to make the knife edge horizontal. The bar can be suspended from any hole with the help of knife edge.

## Principle

The principle is based on the interchangeability of the centres of suspension & oscillation. We know that for a point of suspension, there is another point on the ~~order~~ other side of centre of gravity, known as centre of oscillation about which the time period is the same, there are also two other such points. The distances between centre of suspension and centre of oscillation is known as the length of equivalent simple pendulum. Knowing this distance 'g' can be calculated.


Periodic Time (in sec)
Distance from c.g.
(in meters)

# Observations

## Table for measurement of L & T:

| Sl. No. | No. of hole | Distance of the hole from C.G. (meter) | No. of oscillations | Time Taken (in sec) | Periodic Time T (in seconds) |
|---|---|---|---|---|---|
| 1. | 1 | 0.45 | 10 | 15.79 | 1.579 |
| 2. | 2 | 0.40 | 10 | 15.44 | 1.544 |
| 3. | 3 | 0.35 | 10 | 15.40 | 1.540 |
| 4. | 4 | 0.30 | 10 | 15.35 | 1.535 |
| 5. | 5 | 0.25 | 10 | 15.20 | 1.520 |
| 6. | 6 | 0.20 | 10 | 15.56 | 1.556 |
| 7. | 7 | 0.15 | 10 | 16.53 | 1.653 |
| 8. | 8 | 0.10 | 10 | 19.99 | 1.999 |
| 9. | 9 | 0.05 | 10 | 28.04 | 2.804 |

Positions of centre of gravity. (turn the bar pendulum)

| Sl. No. | No. of hole | Distance of the hole from C.G. (meter) | No. of Oscillations | Time Taken (in sec.) | Periodic Time T (in sec) |
|---|---|---|---|---|---|
| 1. | 19 | 0.45 | 10 | 15.79 | 1.579 |
| 2. | 18 | 0.40 | 10 | 15.44 | 1.544 |
| 3. | 17 | 0.35 | 10 | 15.40 | 1.540 |
| 4. | 16 | 0.30 | 10 | 15.35 | 1.535 |
| 5. | 15 | 0.25 | 10 | 15.20 | 1.520 |
| 6. | 14 | 0.20 | 10 | 15.56 | 1.556 |
| 7. | 13 | 0.15 | 10 | 16.33 | 1.633 |
| 8. | 12 | 0.10 | 10 | 19.99 | 1.999 |
| 9. | 11 | 0.05 | 10 | 28.04 | 2.804 |

## Calculations

Length AC = 0.610 m
Length BD = 0.650 m
Mean Length $L = \frac{AC + BD}{2} = 0.630\ m$

Corresponding Periodic Time (T in sec.) = 1.550 s

$$g = \frac{4\pi^2 L}{T^2} = \frac{4 \times (3.14)^2 \times 0.630}{(1.550)^2} = 10.34\ m/s^2$$

## Percentage error

Standard value of $g = 9.8\ m/s^2$
Experimental value of $g = 10.34\ m/s^2$

$$\text{Percentage error} = \left( \left| \frac{\text{Standard Value} - \text{Experimental value}}{\text{Standard Value}} \right| \times 100 \right) \%$$

$$\Rightarrow \left( \left| \frac{9.8 - 10.34}{9.8} \right| \times 100 \right) \% \Rightarrow \left( \frac{0.54}{9.8} \times 100 \right) \%$$

$$\Rightarrow \boxed{5.51\ \%}$$

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Result :

The value of acceleration due to gravity at New Delhi (name of city) = 10.34 $m/sec^2$

Standard Result

The value of $g$ at New Delhi = 9.8 $m/sec^2$

Precautions

1. Before starting the experiment, the knife edge is made horizontal.
2. The amplitude of oscillation should be kept small.
3. The pendulum should vibrate only in a vertical plane
4. Curves on the graph should be drawn smoothly.

Implication:

Bar Pendulum can be use in many fields (real time) such as Seismometers

To measure seismic ~~activity~~ actively in the ground. It tells from which direction the earthquake was coming when they detect movement, such as shifting of plates due to earthquake, a pendulum with a pen attached to it graphs the magnitude of movement. If the pendulum swings more vigorously, scientists come to know that the seismic waves are intense & potentially dangerous.

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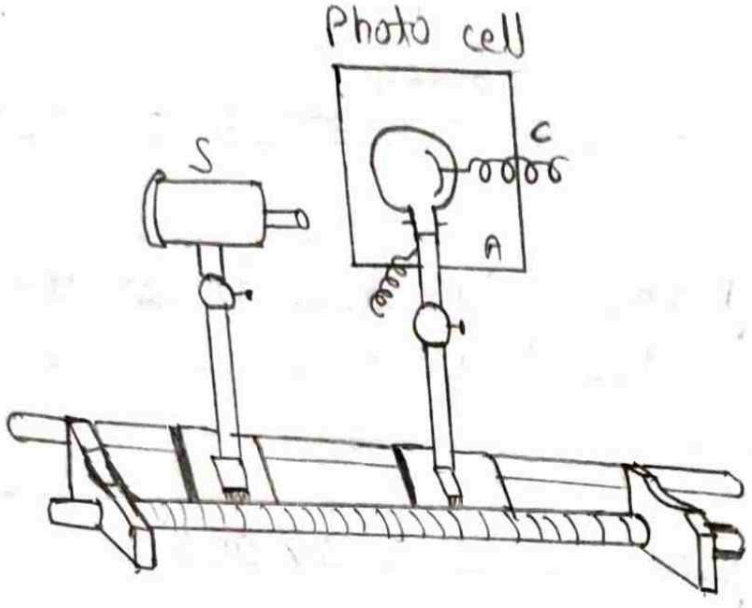



Fig. 2.1 (a)

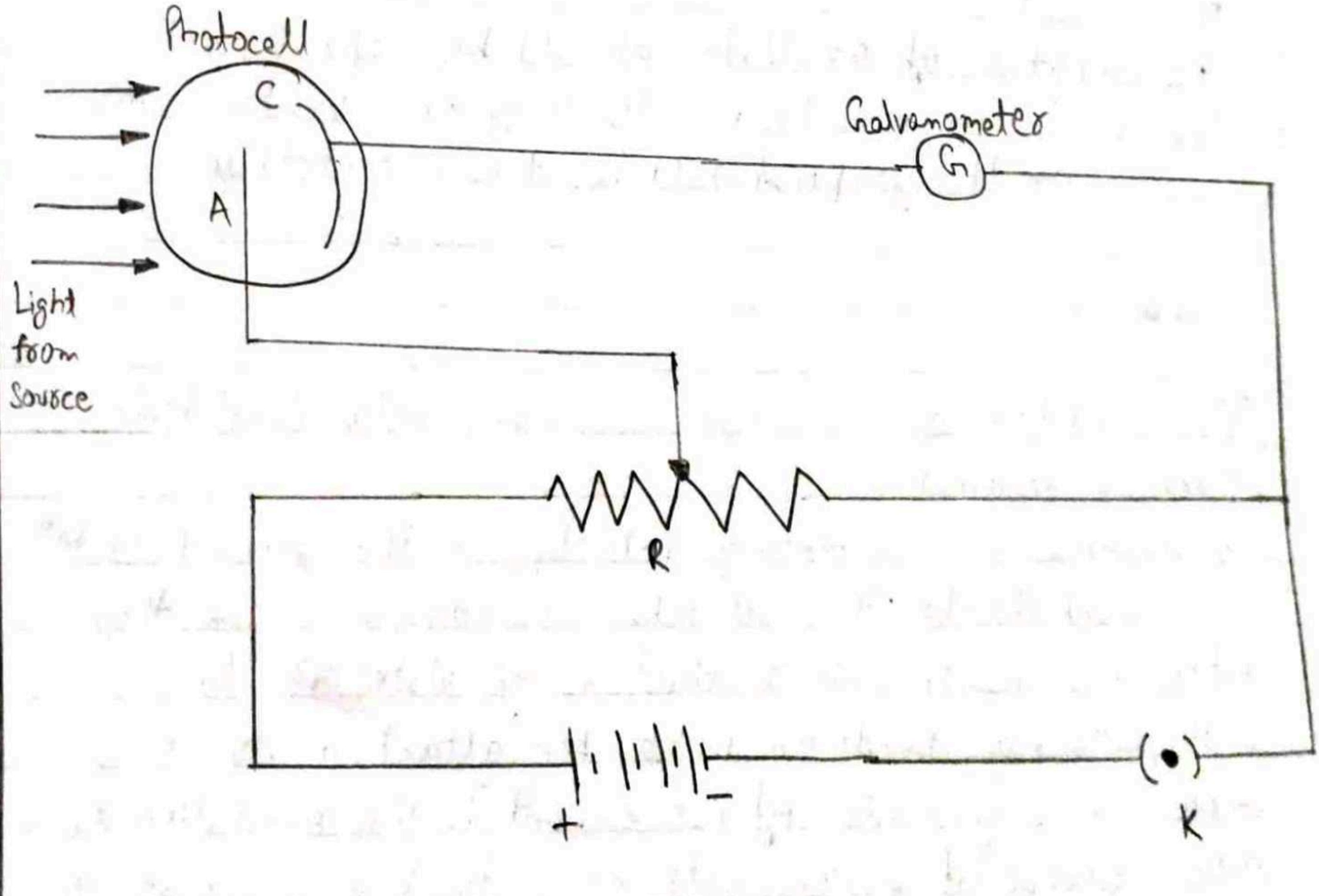



Fig. 2.1 (b)

## Objective

Verify the inverse square law and find the ratio of intensities of two electric bulbs by means of photovoltaic cell

## Apparatus

Two electric bulbs, moving coil galvanometer, lamp and scale arrangement, photovoltaic cell and optical bench with two upright.

## Theory

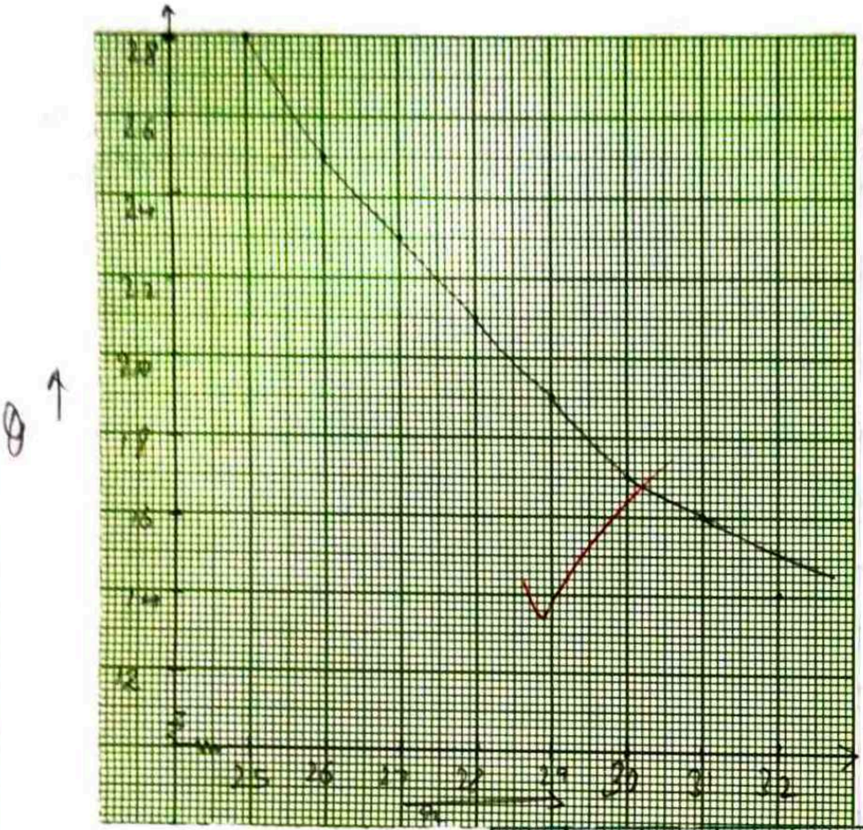
The photovoltaic cell is enclosed in a wooden box having one window that opens towards the bulb. Two terminals of the photovoltaic cell are connected to the two terminals of the moving coil galvanometer. fig 2.1 (b) one of the uprights of the optical bench carries electric bulb & the other upright carries the photovoltaic cell.

Inverse square law of light states that for a source of light having constant luminous intensity, the intensity of illumination (I) at a point on the surface in case of normal incidence is inversely proportional to the square of distance (r) at that point from the source, i.e.,

$$I \propto 1/r^2$$

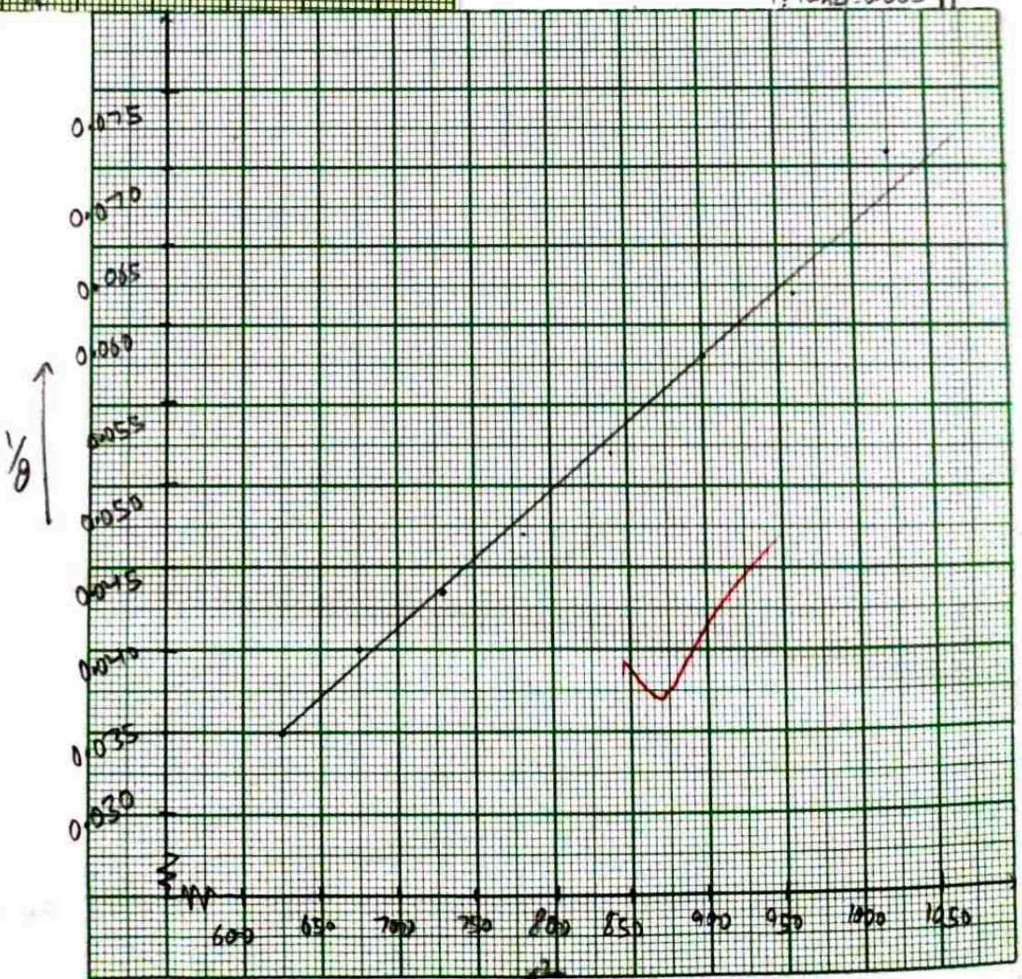
Thus, the intensities of two electric bulbs is expressed as $\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$

▫ Graphs




Scale:
X axis : 1 unit = 1 cm
Y axis : 1 unit = 2

Scale: X: 1 unit = 50
Y: 1 unit = 0.005



where,

$L_1$ = Intensity of first bulb

$r_1$ = distance of first electric bulb from surface of voltaic cell.

$L_2$ = Intensity of second bulb

$r_2$ = distance of second electric bulb from the surface of voltaic cell

The current through the photovoltaic cell is directly proportional to the intensity of illumination. Galvanometer deflection $\theta$ being proportional to current passing through it; we can write

$$\theta \propto I$$

$$\theta \propto 1/r^2$$

Hence, a straight line graph b/w the galvanometer deflection $\theta$ & $I/r^2$ will verify the inverse square law of light.

Observation Table

| S. No. | Position of Upright Photovoltaic cell ($x_1$) | Carrying Lamp ($x_2$) | Galvanometer Deflection ($\theta$) | Difference $r = (x_2 - x_1)$ | $r^2$ ($cm^2$) | $1/\theta$ |
|---|---|---|---|---|---|---|
| 1. | 17 | 42 | 28 | 25 | 625 | 0.035 |
| 2. | 16 | 42 | 25 | 26 | 676 | 0.04 |
| 3. | 15 | 42 | 23 | 27 | 729 | 0.043 |
| 4. | 14 | 42 | 21 | 28 | 784 | 0.047 |
| 5. | 13 | 42 | 19 | 29 | 841 | 0.052 |
| 6. | 12 | 42 | 17 | 30 | 900 | 0.058 |
| 7. | 11 | 42 | 16 | 31 | 961 | 0.062 |
| 8. | 10 | 42 | 14 | 32 | 1024 | 0.071 |

## Calculations

## Results

1. The ratio of intensities of two sources $\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} = 1.07$

2. The obtained graph between $\frac{1}{\theta}$ & $r^2$ proves inverse square law.

## Precautions

1. While taking the readings of the meter, care should be taken to note accurate values.
2. The photovoltaic cell should be exposed to light for long time continuously.
3. The photovoltaic cell & bulbs are mounted in such a way that light falls normally on the surface of the photocell.

## Implications

Inverse square law explains how the radiation propagates in space. There are many applications on inverse square law in various fields. Some of them are:

1. Use of Emr for communication: A signal transmitted from the space craft is received on the earth after travelling distance of 94 AU.

2. In photography & in ~~lightning~~ lighting of stage: The inverse law is used in photography and stage lighting for proper focusing of light on the subject. In making movies we need a proper flash light on studio light. When we are using the flash light or studio light the object that has double the distance from source light can receive only quarter amount of light illumination. Hence if the person moves 4 meters away he needs the four times of light for the exposure

3. In radiology and radiotherapy treatment: Using the inverse square law we can reduce the dose of radiation by reducing the distance. The inverse squarelaw explains how the dose gets reduced by increasing the distance. It can also be said that dose is inversely proportional to square of radius. Thus by doubling the radius we can reduce the dose by a factor of 4.

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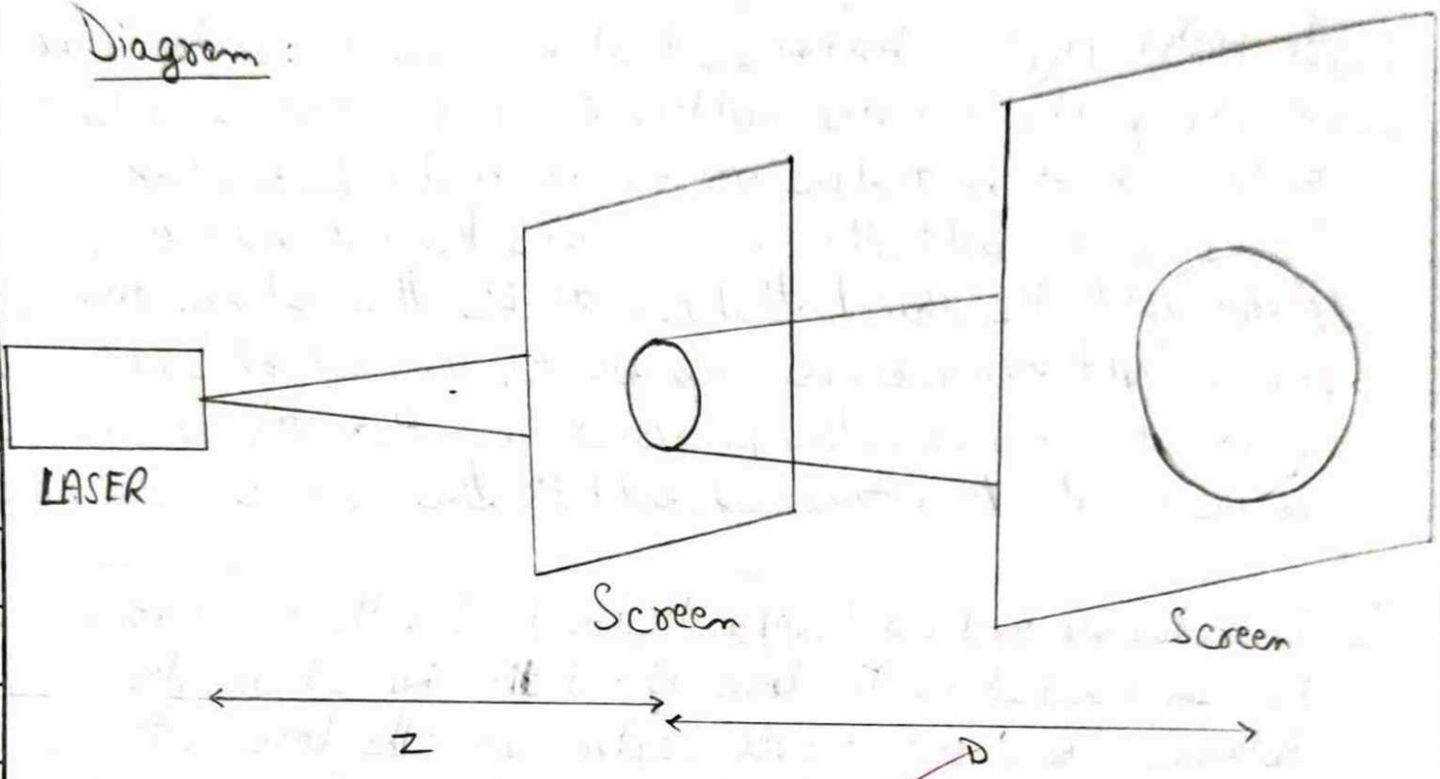
Diagram :



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## Object:

To measure the divergence of the laser beam.

## Apparatus

He-Ne Laser, stand, screen and measuring tape

## Theory

Divergence is defined as the spread of the laser beam i.e. how much angle is subtended by the laser spot at the point of origin. It is measured in ~~radius~~ radian. The divergence of the laser beam is extremely small as compared to the conventional light sources. The typical divergence of a He-Ne laser is of the order of 1 milli radian.

$$\theta = \frac{\sqrt{w_3^2 - 2w_2^2 + w_1^2}}{D\sqrt{2}}$$

## Procedure

The beam spot sizes are measured at 3 different planes at $z = z$, $z + D$, $z + 2D$ respectively. The separation $D$ is measured with a meter scale.

## Result

The average divergence is ~~formed~~ found to be 2 milli radians as expected.



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## Observation Table

| S. No. | Distance (cm) | Spot size (cm)$^2$ 'w' | Divergence 'θ' |
|---|---|---|---|
| 1 | 100 | 0.3 | 2 milli radians |
| 2 | 150 | 0.4 | |
| 3 | 200 | 0.5 | |

## Calculation

$$\theta = \frac{\sqrt{w_3^2 - 2w_2^2 + w_1^2}}{D\sqrt{2}} \rightarrow \frac{\sqrt{0.25 - 0.32 + 0.09}}{50\sqrt{2}}$$

$$\rightarrow \frac{\sqrt{0.02}}{50\sqrt{2}} \rightarrow 0.002 \text{ radian}$$

$\theta = 2$ milli radian

Precautions

(1) Do not ~~stare~~ gaze directly into laser beam.
(2) Measure width of central maxima accurately.

Implication

1. One can calculate the wavelength of light (laser) used in this experiment.

2. One can study the diffraction pattern of laser.

3. We can study the value of N.A. by using laser.

4. S/C Laser are used for printing.

5. LASER can be very useful in measurement of atmospheric pollutants such as dust, smoke and flyash. Pulsed LASER are used for this kind of work.

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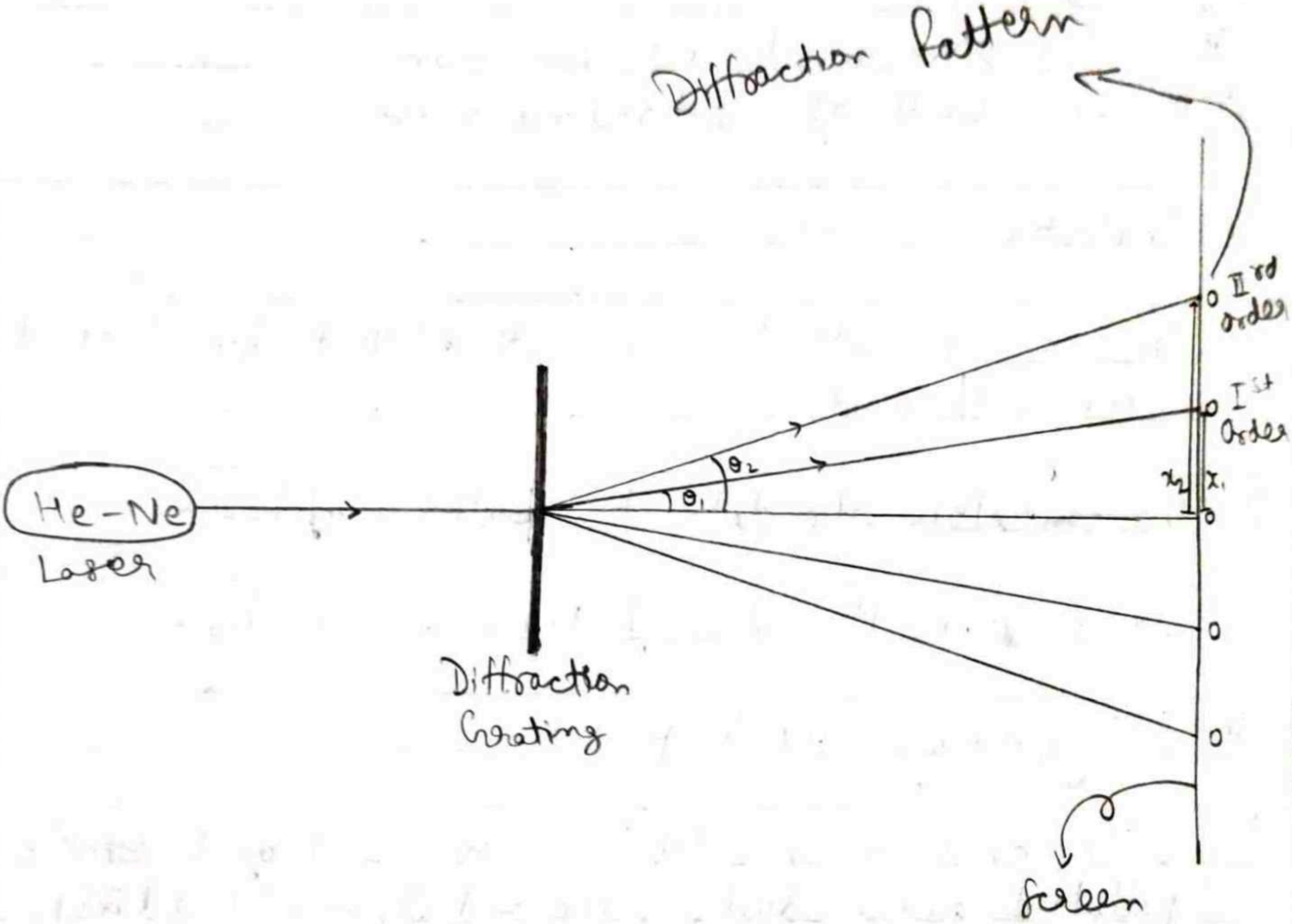

Diffraction Pattern
II nd order
I st order
$\theta_2$
$\theta_1$
$x_2$
$x_1$
He-Ne Laser
Diffraction Grating
Screen


fig. 4.1

**Objective**: To find the wavelength of He-Ne laser source using transmission diffraction grating.

**Apparatus**: He-Ne laser, diffraction grating, optical bench bench with four stands, a screen and metre scale.

**Theory**: When a monochromatic beam of wavelength $\lambda$ is diffracted by a diffraction grating, the nth order principal maxima is formed at an angle $\theta_n$ given by

$$(a+b)\sin\theta = n\lambda \qquad (1)$$

where $(a+b)$ is the grating constant,

$$\lambda = \frac{(a+b)\sin\theta_n}{n} \qquad (2)$$

When laser light is incident on the diffraction grating and diffraction pattern is obtained on the screen formed by a graph, $\sin\theta_n$ can be obtained for different order maximas as shown in the fig 4.1

From the figure, we have

$$\sin\theta_n = \frac{X_n}{\sqrt{L^2+X_n^2}} \simeq \frac{X_n}{L} \qquad (\text{if } L >\!>\!> X_n) \qquad (3)$$

Substituting $\sin\theta_n$ for different orders in equation (2), $\lambda$ can be obtained.

1. Number of lines per inch on grating, N = 15000

2. Grating Constant (a+b) = 2.54/N = 0.000169

3. Distance of screen from grating, L = 80 cm

▫ <u>Observation</u> ÷

| S. No. | Order of Diffraction | Distance of maxima from central spot $X_n$ (cm) | $\sin\theta = \frac{X_n}{\sqrt{L^2+X_n^2}} \simeq X_n/L$ | $\lambda = \frac{(a+b)\sin\theta_n}{n}$ |
|---|---|---|---|---|
| 1. | I | 27.5 | 0.34375 | 0.00005796 |
| 2. | ~~II~~ I | 27.5 | 0.34375 | 0.00005796 |
| 1. | II | 64 | 0.8 | 0.0000676 |
| 2. | II | 65 | 0.8125 | 0.00006865 |

(II) $\sin\theta_n = \frac{64}{80} = 0.8$ (I) $\sin\theta_n = \frac{27.5}{80} = 0.34$

From the figure, we have

$$\sin\theta_n = \frac{X_n}{\sqrt{L^2+X_n^2}} \simeq \frac{X_n}{L}$$

if $L \gg X$, substituting $\sin\theta_n$ for different order

(I) $\lambda = 0.000169 \times 0.34 = 0.00005796$

(II) $\lambda = \frac{0.000169 \times 0.8}{2} = 0.0000676$

$$\lambda_{mean} = \frac{5796+5796+6760+6865}{4} = 6304.2\ A^\circ$$

## Procedure :

→ Mount a diffraction grating on a stand and illuminate it with the laser beam coming from the He-Ne laser source. Place a graph paper pasted on a screen S vertically at a distance of 1 or 2m from the grating. Adjust the distance of screen from the grating till a sharp diffraction pattern in the form of several bright spots of diminishing intensity is obtained. Mark the centre of the spots (maxima) with a pencil.

→ Measure the distance L between the grating and the screen with a metre scale. Also measure the distance of maxima $X_n$ from the central maximum with the help of the scale on the graph-paper.

→ Remove the diffraction grating and measure the diameter d of the direct spot on the screen kept at distance D from the laser source.

→ Repeat for different distances of the screen from the laser.

## Result :

Wavelength of He-Ne laser light $\lambda$ = 6304 A°

## Standard Result:

Wave length of He-Ne laser light $\lambda = 6328 \mathring{A}$

## Precaution:

i) Do not see at the source directly.
ii) The graph used at the screen should be vertically straight.
iii) The diffraction grating should be very near to laser source.

## Implication:

1. Diffraction gratings can be used to produce wavelength monochromatic light of required wavelength.
2. Diffraction gratings are often used in monochromators, spectors, lasers, wavelength, division, multi plexing devices, optical pulse, compressing devices and many other optical instruments.
3. Due to sensitivity to the refractive index of the media diffraction grating can be used as sensor of fluid properties.
4. Moreover, the phenomenon diffraction is used a lot in discovery the structure ~~and~~ of atom. It has been a lot of in discovering medicines and drugs.
5. Diffractions is also fundamental in other application

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## Standard Result :

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such as X rays diffraction studies of crystal and holography

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## Objective

To determine the wavelength of sodium light using Newton's rings setup.

## Apparatus Used

Newton's rings setup (i.e., a planoconvex lens and an optically plane glass plate placed on a wooden stand having a plane glass plate), a travelling microscope, sodium lamp, a convex lens and a spherometer.

## Theory

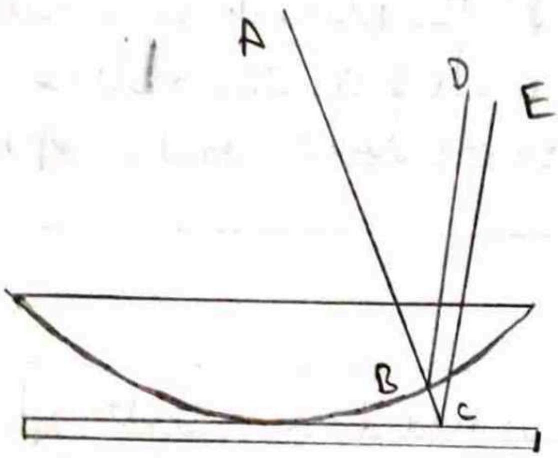
Newton's rings are formed as a result of interference between the waves reflected from the top and bottom of air-film surface formed between the lower convex surface of the lens and the top surface of the plate P. In the figure 2, corresponding to an incident ray AB, the interfering rays are BD and CE and the rings are observed in reflected light. The formulae used to calculate the wavelength of sodium light is given as

$$\lambda = \frac{(D_{n+m})^2 - (D_n)^2}{4mR}$$

where, $D_{n+m}$ is the diameter of $(n+m)^{th}$ dark ring

$D_n$ is the diameter of $n^{th}$ dark ring

$R$ is the radius of curvature of the curved surface of plano-convex lens.


A
D
E
B
c

## Procedure

- → Clean the plano convex lens and two glass plates & fix them as show in figure.
- → Set the glass plate G at an angle of 45°.
- → Switch on the sodium lamp and adjust the position of convex lens $L_1$ so that a parallel beam of light falls on the inclined plate.
- → Place the travelling microscope with its tube vertical above the inclined plate G with its objective above the point of contact of plano-convex lens and the plate P.
- → Focus the eye-piece on the cross wires and focus the microscope so that Newton's rings are clearly visible.
- → Calculate the least count of microscope scale.
- → Clamp the microscope and using its slow motion screw move the microscope horizontally till the cross wire lies beyond $20^{th}$ dark ring on the right hand side of the central dark ring.
- → Note microscope reading on $20^{th}$ dark ring.
- → Now slowly move the microscope towards left & note atleast 8 to 10 readings alternatively on dark rings e.g.; on $18^{th}$, $16^{th}$, $14^{th}$, ---- $2^{nd}$ dark rings.
- → Now go on moving the microscope slowly towards left till it crosses the central dark point and again touches $2^{nd}$ dark ring.
- → Again note the readings on $2^{nd}$, $4^{th}$, - - - $20^{th}$ dark rings.

## Observation Table

- Radius of curvature of curved surface of plano-convex lens = 2
- Vernier constant reading of microscope ____ mm

| S. No. | Order of dark ring | Microscope Reading with cross wires | | Diameter of ring (X−Y) $(D_n)$ mm | $(D_n)^2$ $mm^2$ | $(D_{n+m})^2 - (D_n)^2$ $mm^2$ |
|---|---|---|---|---|---|---|
| | | On Right (X) | On left (Y) | | | |
| 1. | $1^{st}$ | 41.20 | 43.65 | 2.45 | 6.0025 | $(D_5)^2 - (D_1)^2 =$ |
| 2. | $2^{nd}$ | 40.90 | 43.80 | 2.9 | 8.41 | 7.32 |
| 3. | $3^{rd}$ | 40.74 | 43.93 | 3.10 | 10.18 | $(D_6)^2 - (D_2)^2 =$ |
| 4. | $4^{th}$ | 40.62 | 44.06 | 3.44 | 11.83 | 6.41 |
| 5. | $5^{th}$ | 40.51 | 44.16 | 3.65 | 13.32 | $(D_7)^2 - (D_3)^2 = 6.23$ |
| 6. | $6^{th}$ | 40.42 | 44.27 | 3.85 | 14.82 | $(D_8)^2 - (D_4)^2 = 7.77$ |
| 7. | $7^{th}$ | 40.32 | 44.32 | 4.05 | 16.40 | Mean = $\boxed{6.915}$ |
| 8 | $8^{th}$ | 40.8 | 44.65 | 4.42 | 19.54 | |

## ⊛ Calculations :-

$$\lambda = \frac{((D_{n+m})^2 - (D_n)^2)}{4mR}$$

$$= \frac{6.915 \times 10^3}{16}$$

$$\boxed{\lambda = 4321.88\ \mathring{A}}$$

## Errors :-

$$\frac{5890 - 4321.88}{5890} \times 100$$

$$\Rightarrow \boxed{26.62\%}$$

→ Here, care must be taken to note, only those dark rings on left hand side, corresponding to which reading on right hand side were noted.
→ Calculate the diameter $D_n$ & $(D_n)^2$ of each $n^{th}$ dark rings.
→ Set the value of m and determine $(D_{n+m})^2$.
→ Calculate $(D_{n+m})^2 - (D_n)^2$ and determine the wavelength of light using the given formula.

□ Result

Wavelength of sodium light as obtained by Newton's rings method = 4321.88 Å

· Actual value of λ of Na light = 5890 Å

· Percentage of error = 26.62 %

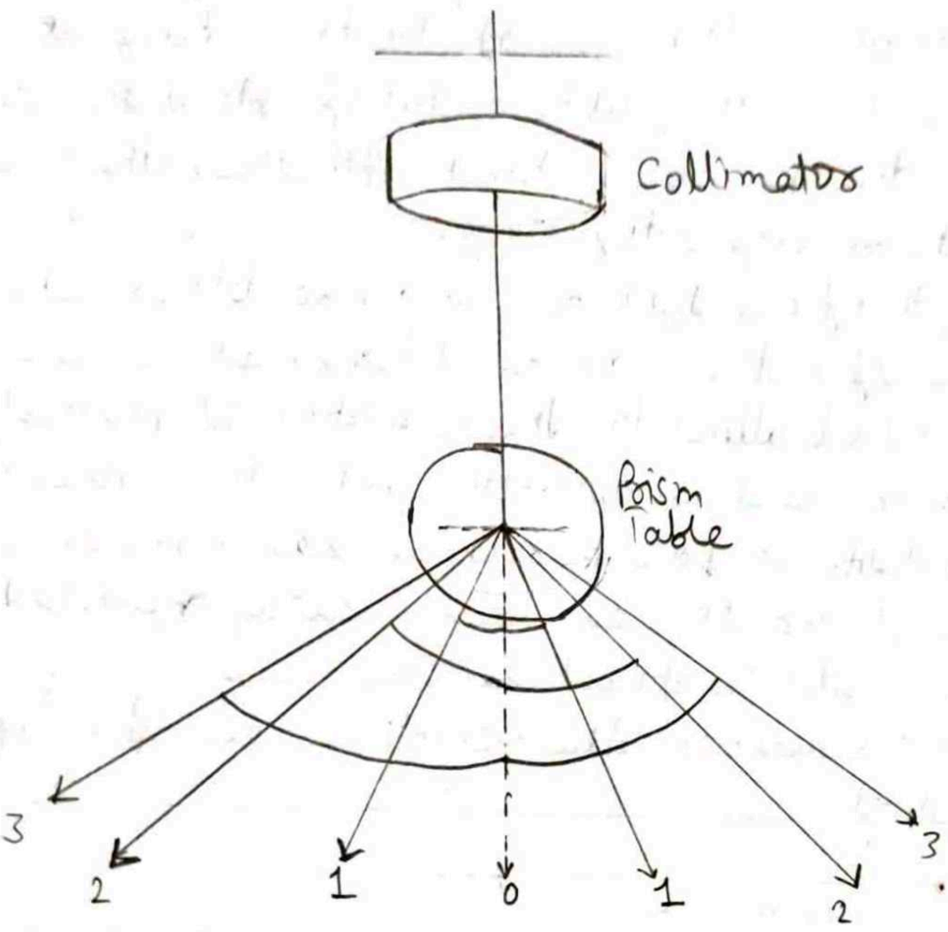
□ Precautions

→ The source of light should be an extended one.
→ The plano-convex lens and the glass plate should be cleaned thoroughly
→ Cross-wire should be adjusted on the dark rings tangentially
→ Newton's ring setup should not be disturbed during the whole set of observations.

## Implications

1. The interference technique of Newton's Ring ~~is~~ is widely used for the quality control of optical surface because the precision obtained with this method proves to be very satisfactory.
2. Wavelength of any light source can be determined.
3. Thickness of a thin can be determined.
4. FRED model allow for the simulation of physical optics Phenomenon such as diffraction and interference. With this capability components such as Gau Guassian laser beams & interferometer can be accurately modeled & Incorporated into optical systems.
5. Using this experiment the refractive index of a liquid ~~co~~ can be calculated.

## Diagram



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## Objective

To determine the wavelength of sodium light by plane diffraction grating.

## Apparatus Required

Spectrometer, Prism Table, Sodium lamp, reading lens and a diffraction grating.

## Formula Used:

The wavelength $\lambda$ of any ~~spectal~~ spectral lines can be calculated by the formula

$$\lambda = \frac{(a+b)\sin\theta}{n}$$

where $(a+b)$ = grating element

$\theta$ = angle of diffraction

$n$ = order of spectrum

## Procedure:

The collimator must intersect the principal vertical axis of rotation of telescope. Collimator and telescope are arranged in a line and the image on the slit is focused on the vertical cross wire.

1. Now the slit is rotated in its own plane till the spectral lines become very sharp and bright.

## Observation Table

No. of rulings per inch on the grating, N = 15000

Least Count of spectrometer = 1/60

| S. No. | Order of diffractions (n) | Scale | Image on the left side: Main Scale | Vernier Scale | Total Reading (a) | Image on the right side: Main Scale | Vernier Scale | Total Reading (b) | $\theta = \frac{a-b}{2}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 1 | $V_1$ | $330 + 14\times\frac{1}{2}$ | $10\times\frac{1}{60}$ | 337.16 | $10+2\times\frac{1}{2}$ | 3/60 | 371.05 | 16.945 |
| | 1 | $V_2$ | $150 + 14\times\frac{1}{2}$ | $20\times\frac{1}{60}$ | 157.33 | $190+2\times\frac{1}{2}$ | $10\times\frac{1}{60}$ | 141.166 | 16.918 |

$$\theta_{mean} = \frac{\theta_1+\theta_2}{2} = 16.9315$$
$n = 1$

## Calculations

Grating element $(a+b) = 2.54/N = 0.00016933$ per cm
where N = no. of ruling per inch on the grating

The wavelength of sodium light can be calculated by
$$\lambda = \frac{(a+b)\sin\theta}{n}$$
where $n=1$ for the first order and $n=2$ for second order.
$$\lambda = \frac{0.00016933 \times \sin(16.9315)}{10^8 \times 1} = 4931.46\,\text{Å}$$

$$\%\ \text{error} = \left(\frac{5896 - 4931.46}{5896}\right)\times 100 \Rightarrow 16.36\%$$

2. Rotate the telescope to the left side of direct image and adjust the line on the vertical cross wire for $1^{st}$ order. Note down the reading of both the verniers in each setting.
3. Rotate the telescope further to obtain the second order spectrum and again the spectral lines on the vertical cross wire and note the readings.
4. Now rotate the telescope to the right of the direct image and repeat the above procedure for first order as well as for second order.
5. Find out the difference of the same kind of verniers ($V_1$ from $V_1$ and $V_2$ from $V_2$) or the line in the first order and then in the second order. The angle is the twice the angle of diffraction.

- Result

The wavelength of sodium light is found to be 4931.46 Å

- Sources of error and precautions

1. Before performing the experiment, the spectrometer should be adjusted.
2. Grating should set normal to the incident light.
3. Grating should not be touched by fingers.
4. While taking observations, telescope and prism table ~~is~~ kept fixed.

## Implications

1. Diffraction gratings can be used to ~~pro~~ produce ~~monochrom~~ monochromatic light of required wavelength.
2. Diffraction grating are often used in monochromators, spectrometers, Lasers, wavelength division, multiplexing devices, optical pulse compressing devices and many other optical Instruments.
3. Due to the sensitivity to the refractive index of the media diffraction grating can be use as sensors of fluid properties.
4. Moreover, the phenomenon diffraction is used a lot in discovery the structures and atoms. It has been used a lot in discovering medicines and drugs.
5. Diffraction is also fundamental in other applications such as X-Ray diffraction studies of crystal and holography.

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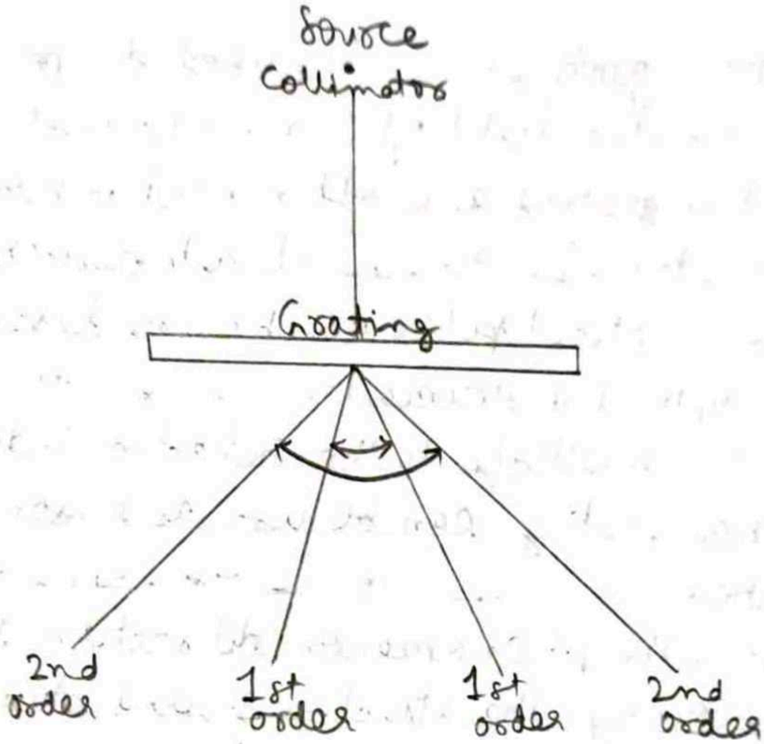
▫ Diagram


Source
Collimator
Grating
2nd order
1st order
1st order
2nd order

## Objective

To determine the resolving power of grating.

## Apparatus Used

Plane diffraction grating, spectrometer, mercury lamp, reading lens.

## Formula Used

The resolving power $\lambda/d\lambda$ of a plane diffraction grating is given by:

$$R.P. = \lambda/d\lambda = N_o n$$

Where,

$d\lambda$ = the smallest wavelength difference b/w the two spectral lines which are just resolved by grating.

$\lambda$ = the mean wavelength of two spectral lines which are just resolved.

$N_o$ = the total no. of lines in the exposed width of the grating in just resolution position.

$n$ = order of the spectrum

## Procedure

1. The spectrometer adjustments are made as described under the spectrometer head in the general section on refraction & dispersion of light.

OBSERVATION

No. of lines per cm of the grating (grating element)

$$a+b = 2.54/N = 0.0001693 \text{ cm}^{-1}$$

Least count of spectrometer = $1 \times 1/60$

Table for 1st line:

| S.No | Order | Color | Scale | Img on left side | | | Direct Image | | | $\theta_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Main Scale | Vernier Scale | Total Reading | Main Scale | Vernier Scale | Total Reading | |
| 1. | 1 | Yellow | $V_1$ | 184.5 | 11/60 | 184.683 | 203 | 10/60 | 203.167 | +18.484 |
| | 1 | Yellow | $V_2$ | 4.5 | 25/60 | 4.917 | 21.5 | 11/60 | 21.683 | +16.766 |

Mean $\theta_1$ = 17.625

Table for 2nd lines:

| S No. | Order | Color | Scale | Image on left side | | | Direct Image | | | $\theta_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Main scale | Vernier Scale | Total Reading | Main Scale | Vernier Scale | Total Reading | |
| 1. | 1 | Yellow | $V_1$ | 184 | 16/60 | 184.267 | 203 | 10/60 | 203.167 | +18.9 |
| | 1 | Yellow | $V_2$ | 4 | 4/60 | 4.067 | 21.5 | 11/60 | 21.683 | +17.61 |

Mean $\theta_2$ = 18.258

2. The slit should be adjusted parallel to the ruling of the grating.

3. Rotate the telescope to the left side of the direct image and you will get the spectrum. Now there would be two lines of each color.

4. Choose a color (say yellow), adjust the 1st line on the vertical cross wire for 1st order. Note down the reading of both the verniers. Now adjust the 2nd line on the vertical cross wire and again note down the reading of both the verniers.

5. Rotate the telescope further to obtain the second order spectrum and again the spectral lines on the vertical cross wire and note the readings.

6. Now rotate the telescope to the direct image and note down the readings of both verniers.

7. Repeat the experiment for different colors.

## Result

The resolving power of a given grating for yellow color is found to be 29.14

Calculations :

$$\lambda_1 = \frac{(a+b)\sin\theta_1}{n} = \frac{0.0001693 \times \sin(17.625)}{1\times10^{8}} \approx 5126\ \text{Å}$$

$$\lambda_2 = \frac{(a+b)\sin\theta_2}{n} = \frac{0.0001693 \times \sin(18.258)}{1\times10^{8}} \approx 5304\ \text{Å}$$

$$\lambda = \frac{\lambda_1+\lambda_2}{2} = 5215\ \text{Å}$$

$$\text{Resolving Power} = \frac{\lambda}{\Delta\lambda} = \frac{5215\ \text{Å}}{(5304-5126)\ \text{Å}} \approx 29.14$$

Theoretical

The difference in wavelengths of two yellow lines of Hg spectrum

$$\lambda_1 - \lambda_2 = \Delta\lambda$$

$$5790 - 5770 = 20$$

$$\text{Mean wavelength} = 5780$$

$$\text{Theoretical Resolving Power} = \frac{5780}{20} = 289$$

% error

$$\frac{(\text{Theoretical} - \text{observed})\ \text{value}}{\text{Theoretical value}} \times 100 \Rightarrow \frac{(29.14 - 28.9)}{29.14} \times 100$$

$$\Rightarrow 0.8236\ \%$$

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## Sources of Error and Precautions

1. Before performing the experiment, the spectrometer should be adjusted.
2. Grating should be set normal to the incident light.
3. Grating should not be touched by fingers.
4. While taking observations, telescope and prism table should be kept fixed.

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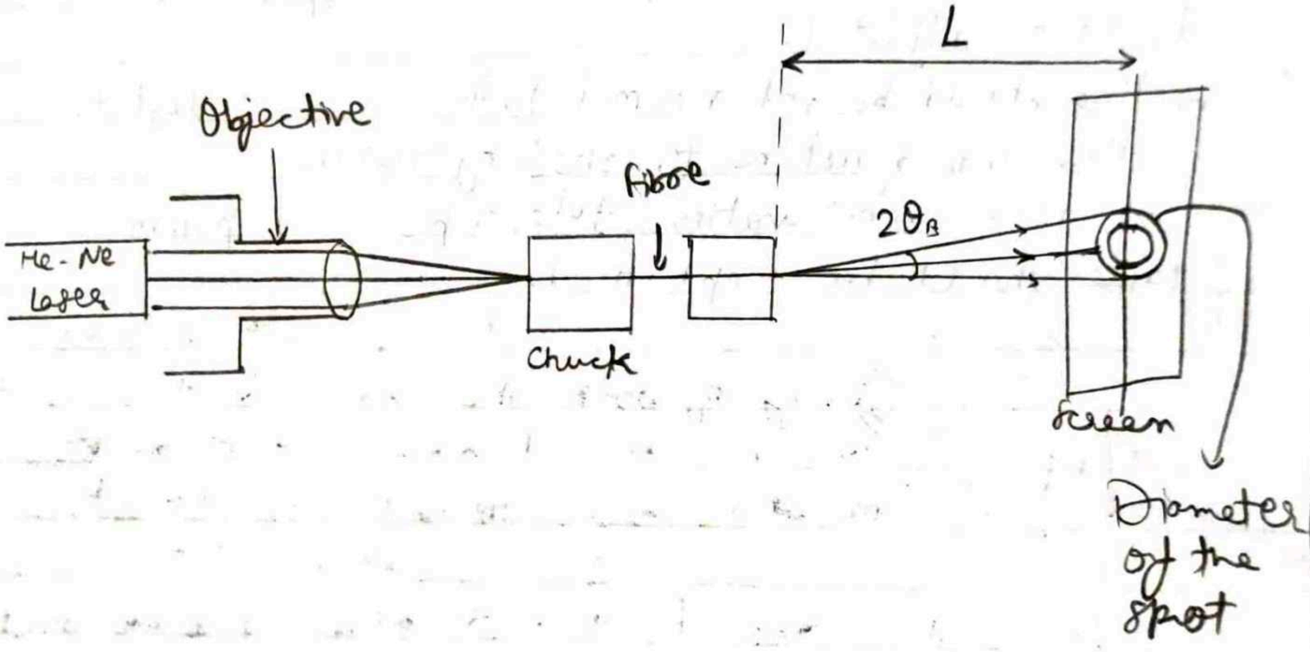

L
Objective
fibre
$2\theta_B$
He-Ne laser
Chuck
Screen
Diameter of the spot


D
L

- **Objective**: To determine the numerical aperture (NA) of an optical fibre.

- **Apparatus**: Optical-fibre, two fibre optic chucks, He-Ne laser, a microscopic objective and a screen with a graph paper pasted on it.

- **Theory**:

~~Students are adviced to go through~~.

Numerical aperture (NA) of the optical fibre is a measure of light gathering ability of the fibre and an important parameter which determines the angle of the "light acceptance cone" ($\theta_a$) at the input of the fibre. The numerical aperture is defined as the sine of half angle of the acceptance cone. It is ~~gen~~ given as

$$NA = \sin\theta_a = \sqrt{\mu_f^2 - \mu_c^2}$$

~~Here~~ Where $\mu_f$ & $\mu_c$ are refractive index of core & refractive index of cladding respectively. Thus, to determine the numerical aperture, the acceptance angle $\theta_a$ of the fibre should be known.

In a short length of optical fibre; ideally a ray entering at an angle i at the input end comes out at the same angle i from the output end. Therefore, the emerging rays from the output end

| S. No. | Distance b/w output end of optical fibre and screen L (cm) | Diameter of circular spot D (cm) | $NA = \frac{D}{\sqrt{D^2 + 4L^2}}$ |
|---|---|---|---|
| 1. | 1 | 1.2 | 0.5145 |
| 2. | 1.7 | 1.7 | 0.4472 |
| 3. | 2.1 | 2.9 | 0.5682 |

Mean NA = $0.5099\overline{6}$

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of the fibre will appear as a cone of semi-angle θ. It is thus easy to make measurements on this end of the fibre to determine the numerical aperture of the fibre. If the emerging rays from the output end of the optical fibre make a spot of diameter D on a screen kept at a distance L from the output end of the fibre. ~~then~~

$$\sin\theta_a = \frac{D/2}{\sqrt{(D/2)^2 + L^2}} = \frac{D}{\sqrt{D^2+4L^2}}$$

$$NA = \frac{D}{\sqrt{D^2+4L^2}}$$

- Procedure

1. Insert both the ends of the optical fibre in the fibre optic chucks mounted in the uprights on an optical bench.
2. Switch on He-Ne laser.
3. Adjust the He-Ne laser so that laser beam is coupled into one of the fibre ends through a 20X microscopic objective mounted in an upright position.
4. Fix a graph ~~screen~~ sheet on the screen mounted in an upright.
5. Place the screen at some distance at the other end of optical fibre (i.e. output end) such that it is perpen

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-icular to the axis of the ~~flow~~ fibre.

6. Adjust the position of the screen by moving it towards or away from the output end of fibre so that a bright circular spot is formed on the screen.
7. Measure the diameter of the circular spot formed on the screen. Let it be D. Also measure the distance b/w the output end of optical fibre and screen. Let it be L.
8. Repeat the experiment to ~~tape~~ take at least four observations for different values of L & D.

- **Result**

Numerical Aperture = 0.5099$\bar{6}$

- **Precautions**

1. Optical fibre should not bend when the light is being propagated.
2. Light should be coupled properly into the fibre so that a bright spot of light is obtained.
3. Losses due to bending, leakage, dispersion, etc. should be minimised.
4. We should ensure accurate measurement of diameter of the spot.
5. Optical fibre axis should be parallel to optical bench.

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## Sources of Error

1. There may be losses due to bending, radiation and leakage, etc.
2. The edges or ends of the optical fibre might not be sharply cut and the bright spot may not be exactly circular.
3. The intensity of light is reduced as the distance between the screen and output end of fibre is increased.

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