THE COCHIN COLLEGE

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LEAD KINDLY LIGHT
THE COCHIN COLLEGE

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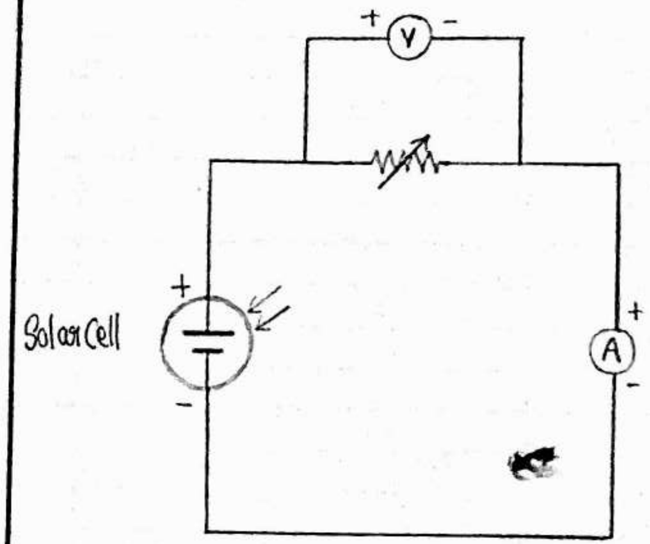
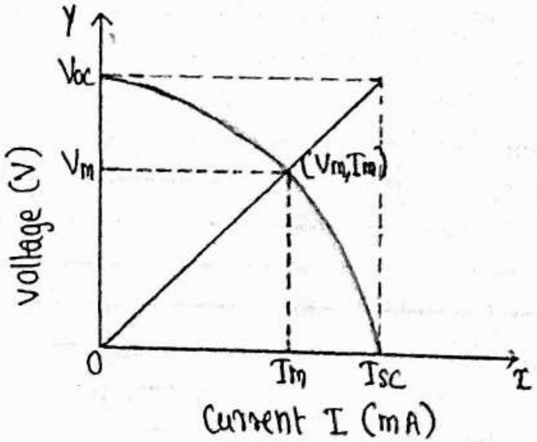
CIRCUIT DIAGRAM



I-V CHARACTERISTICS



EXPERIMENT 1 DATE – 10/11/2023

SOLAR CELL - EFFICIENCY & FILL FACTOR

AIM

To plot the V-I characteristics of the solar cell and hence determine the fill factor and efficiency.

APPARATUS REQUIRED

Solar cell, Light Source, Resistance box, multimeter, connecting wires

THEORY

The solar cell is a semiconductor device, which converts the solar energy into electrical energy. It is also called a photovoltaic cell. A solar panel consists of numbers of solar cells connected in series or parallel. The number of solar cells connected in a series generates the desired output voltage and connected in parallel generates the desired output current. The conversion of solar energy into electric energy takes place only when the light is falling on the cells of the solar panel. A solar cell operates in somewhat the same manner as other junction photo detectors. A built in depletion region is generated in that without an applied reverse bias and photons of adequate energy create hole electrons pairs. When a load is

OBSERVATIONS:

Distance between solarcell and light source = 36.5 cm

Load resistance RL (Ω)	voltage (V)	Current I (mA)
0	0	2.45
100	0.25	2.47
200	0.50	2.46
300	0.76	2.46
400	1.01	2.48
500	1.171	2.47
600	1.173	2.47
800	1.172	2.44
1000	1.173	2.45
2000	1.186	2.10
3000	1.21	1.57
4000	1.22	1.22
5000	1.24	1.00
6000	1.26	0.84
7000	1.27	0.73
8000	1.28	0.64
9000	1.29	0.57
10,000	1.31	0.52
20,000	1.32	0.26
∞	1.38	0

connected across the cell, the potential causes the photo-current to flow through the load. The emf generated by the photo-voltaic cell in the open circuit ie, when no current is drawn from it is denoted by Voc, called open circuit voltage. This is the maximum value of emf. when a high resistance is introduced in the external circuit a small current flows through it and the voltage decreases. The voltage goes on falling and the current goes on increasing as the resistance in the external circuit is reduced. when the resistance is reduced to zero the current rises to its maximum value known as saturation current and is denoted as Isc, the voltage becomes zero. A V-I characteristic of a photo voltaic cell is showned in the figure.

The product of open circuit voltage Voc and short circuit current Isc is known as an ideal power.

Ideal power $= V_{oc} \times I_{sc}$

The maximum useful power is the area of the largest rectangle that can be formed under the V-I curve. If V_m and I_m are the values of voltage and current under this condition, then

maximum useful power, $P_{max} = V_m \times I_m$

The ratio of the maximum useful power to ideal power is called the fill factor. Therefore.

Fill Factor, $FF = \frac{V_m \times I_m}{V_{oc} \times I_{sc}}$

Efficiency of solar cell refers to the ratio of energy output from the solar cell to the input energy from the sun, here we are using a incandescent lamp.

Efficiency, $\eta = \frac{P_{out}}{P_{in}}$

$P_{out} = P_{max} = V_m \times I_m$

$P_{in} = I A_c$

where I is the irradiance, which is the amount of light energy incident on every square metre of a surface per second.

Irradiance, $I = \frac{E}{At} = \frac{P}{A} = \frac{P_{source}}{4\pi d^2}$

where P - power in watt's of the light.

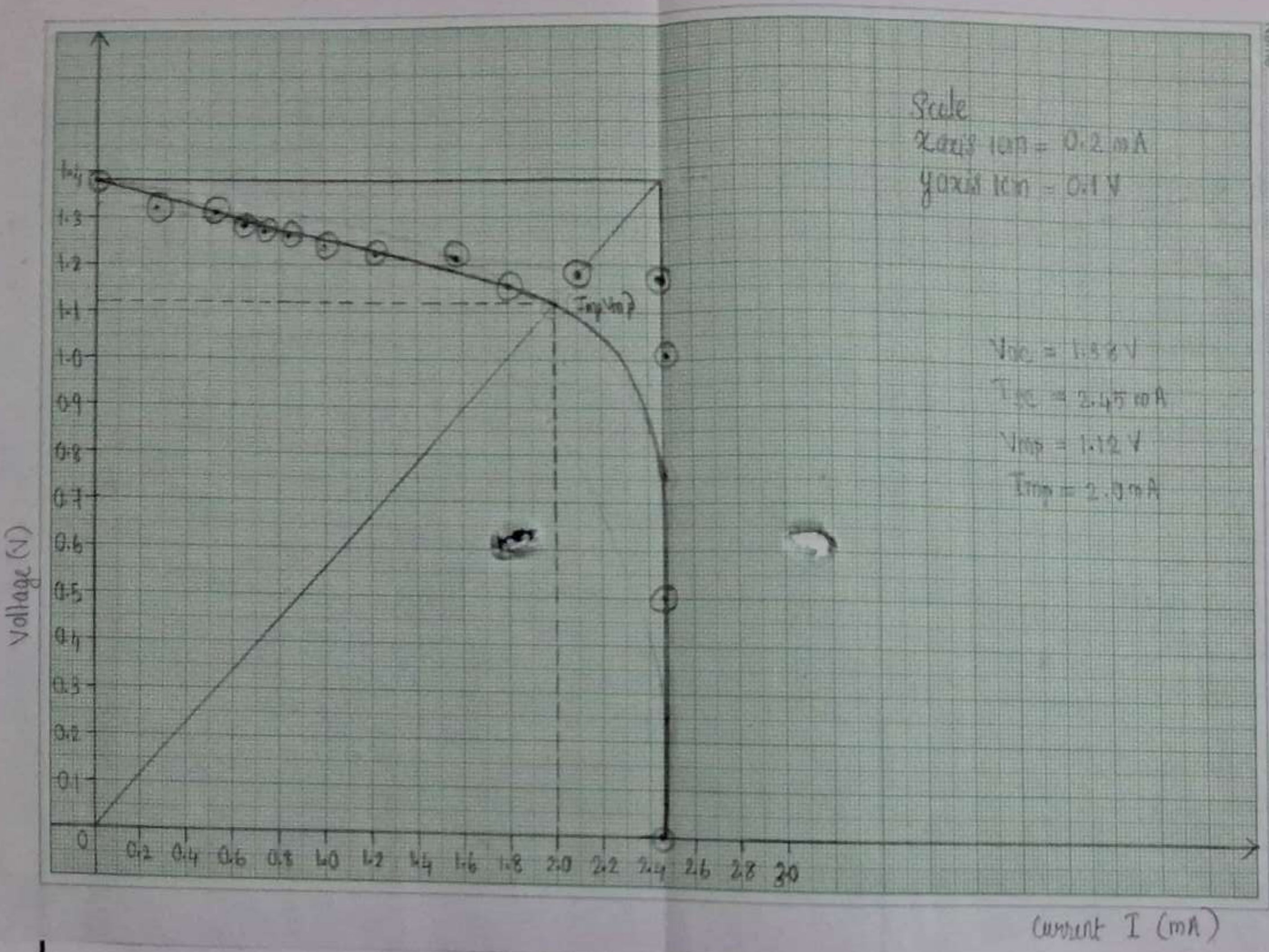
A - Area of the sphere on which the energy is projected out from the sun.

$A = 4\pi d^2$

where d - distance between light source and solar cell

In general, Efficiency $\eta = \frac{V_m I_m}{I A_c}$

$I = \frac{P_{source}}{4\pi d^2}$



$\dfrac{V_m \times I_m}{V_{oc} \times I_{sc}}$

r cell refers to the ratio of energy solar cell to the input energy from e are using a incandescent lamp.

$\dfrac{P_{out}}{P_{in}}$

ax $= V_m \times I_m$

Ac

irradiance, which is the amount incident on every square metre of second.

$I = \dfrac{E}{At} = \dfrac{P}{A} = \dfrac{P_{source}}{4\pi d^2}$

ower in watt's of the light
area of the sphere on which the energy s projected out from the sun
πd^2.

where d - distance between light source and solar cell

In general, Efficiency $\eta = \dfrac{V_m I_m}{I\,A_c}$

$I = \dfrac{P_{source}}{4\pi d^2}$

From graph

$I_{sc} = 2.45 mA$ $V_{oc} = 1.38 V$

$I_{mp} = 2.0 mA$ $V_{mp} = 1.12 V$

Fill factor $FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} = \frac{1.12 \times 2.0 \times 10^{-3}}{1.38 \times 2.45 \times 10^{-3}} \times 100 = \underline{\underline{66.25\%}}$

The fill factor for silicon devices may vary from 70 to 82%

Error percentage in fill factor $= \frac{0.70 - 0.6625}{0.7} \times 100$

$= \underline{\underline{5.3\%}}$

Efficiency, $\eta = \frac{P_{out}}{P_{in}} = \frac{V_{mp} I_{mp}}{E\,A_c}$, $A_c = 30 \times 10^{-4}\ m^2$.

$E = \frac{P_{source}}{4\pi d^2}$, $d = 36.5\ cm$,

we are using 100W incandacent lamp, among this only 5%6% of the electrical energy is converted into light, and 94-98% is lost as heat. Assume 6% of lamp's power is converted to visible light.

$\therefore P_{source} = 6W$

Then $E = \frac{6}{4 \times 3.14 \times (36.5 \times 10^{-2})^2} = 3.58\ W/m^2$

PROCEDURE

1- Place the solar cell and the light source (100W) opposite to each other on a wooden plank. Connect the circuit as shown in the figure through patch chords.

2- Select the voltmeter range to 2V, current meter range to 2.5 mA and load resistance R_L to ∞

3- Switch ON the lamp to expose the light on solar cell.

4- set the distance between the solar cell and lamp in such a way that the current meter shows 2.5 mA deflections. Note down the observation of voltage and current.

5- Vary the load resistance using a resistance box and note down the current and voltage readings every time..

6 - plot a graph between output voltage vs output current by taking voltage along y-axis and current along x axis.

7 - Determining fill factor and efficiency

Draw a rectangle having maximum area under the V-I curve and note the values of Vm and Im. Note the voltmeter reading for open circuit Voc and milliammeter reading with zero resistance, Isc. Using these values, we can calculate the fill factor and efficiency for the cell.

$$\eta = \frac{1.12 \times 2 \times 10^{-3}}{3.58 \times 30 \times 10^{-4}} = \frac{0.00224}{0.01074} = \underline{\underline{0.208}}$$

maximum efficiency of practically used solar cells is about 0.2 (20%)

Error percentage in efficiency, $\eta = \frac{0.208 - 0.2}{0.2} \times 100$

$= \underline{\underline{4\%}}$

RESULT

V-I characteristics of solar cell plotted

Solar cell Fill Factor, FF = 66.25%

Ideal value = 70% to 82%

Error percentage = 5.3%

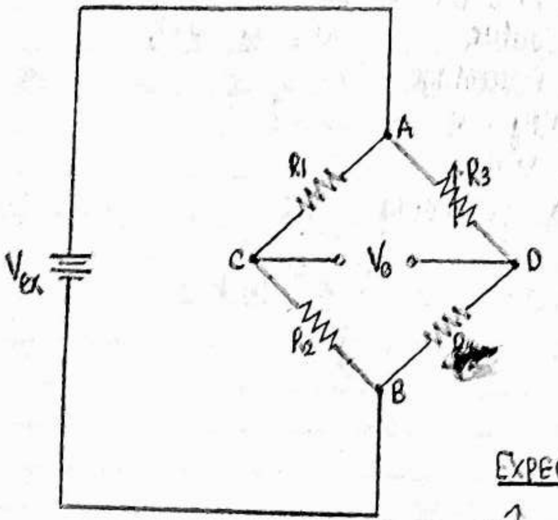
Solar cell Efficiency, η = 20.8%

Ideal value = 20%

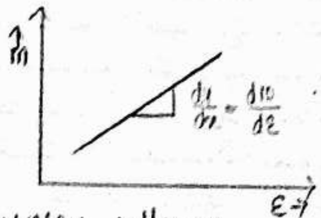
Error percentage = 4%

5/7/24

A BASIC WHEATSTONE BRIDGE CONFIGURATION



EXPECTED GRAPH



$V_{ex} = 1.25V$
$G_F = 3.7$

The values measured using vernier calliper,

Breadth of the cantilever, b = 2.67 cm

The value measured using Screw gauge

Thickness of the cantilever, t = 0.20 cm

EXPERIMENT 2 DATE ~ 3/2/2024

YOUNG'S MODULUS-STRAIN GAUGE

AIM

To determine the Young's modulus of a cantilever using strain gauge

APPARATUS REQUIRED

An aluminum cantilever fitted with strain gauge 50×5g slotted weight, a digital strain gauge voltage indicator.

THEORY

A strain gauge is a device used to measure the amount of strain (deformation) in an object. It consists of a thin, electrically conductive foil pattern that is mounted on a backing material, which can be adhered to the surface of the object being measured. When the object deforms due to an applied force, the strain gauge deforms as well, causing a change in its electrical resistance. This change in resistance can be measured and is proportional to the strain experienced by the object.

The resistance of a conducting strain gauge wire can be expressed using the following equation.

$$R = \frac{\rho L}{A} \quad (1)$$

Observation and Calculations

At : $x = 9\ cm = 9 \times 10^{-2}\ m$

Weight (g)	Trial 1 $\times 10^{-3}$ V	Trial 2 $\times 10^{-3}$ V	Trial 3 $\times 10^{-3}$ V	Average V_0 ($\times 10^{-3}$ V)	$\varepsilon = \frac{V_0}{GF \cdot V_{ex}}$ ($\times 10^{-6}$)	m/ε ($\times 10^{6}$)
0	0	0	0	0	0	
50	0.09	0.09	0.09	0.09	19.46	2.57
100	0.18	0.18	0.18	0.18	38.91	2.57
150	0.27	0.27	0.27	0.27	58.37	2.57
200	0.36	0.36	0.36	0.36	77.83	2.57
250	0.45	0.45	0.45	0.45	97.29	2.57
300	0.54	0.54	0.54	0.54	116.75	2.57

mean $m/\varepsilon = 2.57 \times 10^{6}\ g$

Young's modulus, $Y = \frac{3mgx}{bt^2\varepsilon}$

$$= \frac{3 \times 980 \times 9}{2.67 \times (0.20)^2} \times 2.57 \times 10^{6}$$

$$= 6.367 \times 10^{11}\ \frac{g\ cm/s^2\ cm}{cm^3}$$

$$= 6.367 \times 10^{11}\ dyne/cm^2 = 6.367 \times 10^{10}\ N/m^2$$

where,

R – is the resistance of the strain gauge wire.
ρ – is the electrical resistivity of the material of the wire.
L – Length of the wire.
A – is the cross-sectional area of the wire

The ratio of the relative change in electrical resistance to the mechanical strain experienced by the strain gauge is known as gauge factor G_F. Mathematically it is expressed as:

$$G_F = \frac{\Delta R/R}{\varepsilon} \quad (2)$$

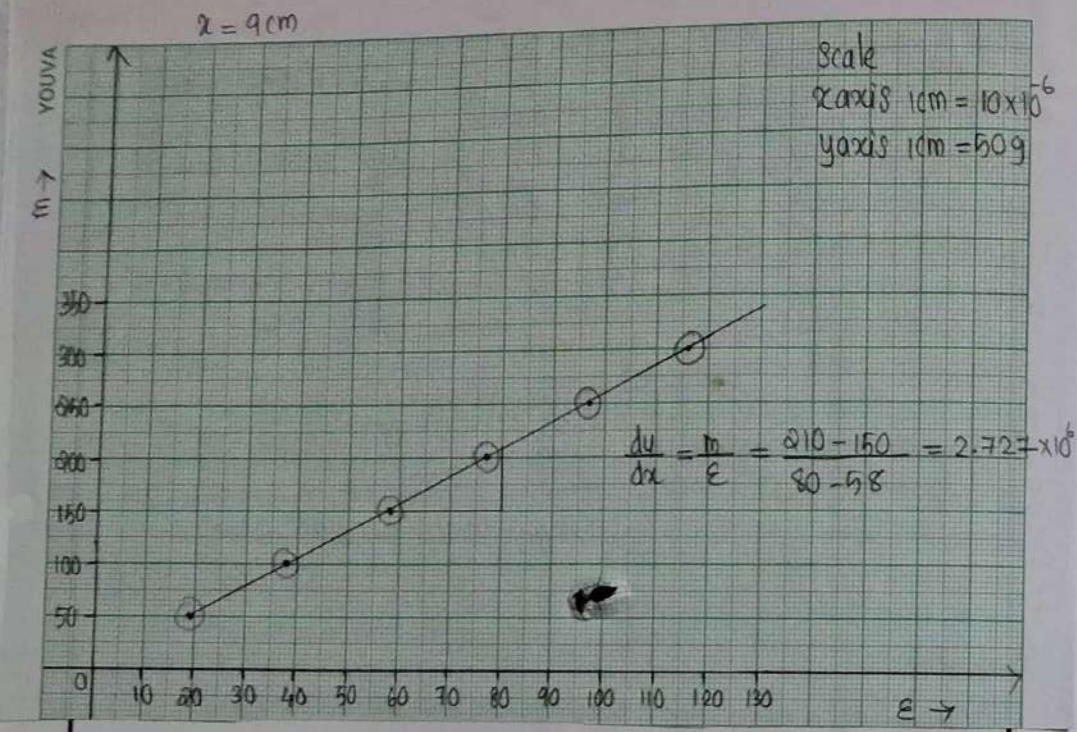
where,

ΔR – the change in resistance due to strain
R – original resistance
ε – Strain experienced by the strain gauge.

For most metallic strain gauges, the gauge factor is typically around 2, but it can vary depending on the material and construction of the strain gauge.

Strain (ε) detected by the strain gauge can be calculated from the output voltage using gauge factor (GF):

$$\varepsilon = \frac{V_0}{GF \cdot V_{ex}} \quad (3)$$



From graph

$$\frac{m}{\varepsilon} = 2.727\times10^{6}\ g$$

$$Y = \frac{3gx}{bt^2}\times\frac{m}{\varepsilon}$$

$$= \frac{3\times980\times9}{2.67(0.2)^2}\times2.727\times10^{6}$$

$$= \underline{\underline{6.756\times10^{11}}}\ dyne/cm^2 = \underline{\underline{6.756\times10^{10}}}\ N/m^2$$

Mean value of $Y = \frac{[6.367\times10^{11}]+[6.756\times10^{11}]}{2} = \underline{\underline{6.562\times10^{11}}}\ dyne/cm^2$

where,

Vo – Output voltage from the strain gauge.
GF – Gauge factor of the strain gauge
Vex – excitation voltage applied to the wheatstone bridge.

The strain gauge is used in conjunction with a wheatstone bridge to measure the small changes in electrical resistance that occur when the strain gauge is deformed due to mechanical stress.

A wheatstone bridge is an electrical circuit used to measure unknown electrical resistances by balancing 2 legs of a bridge circuit. It consists of 4 resistances arranged in a diamond shape. The basic wheatstone bridge configuration is shown and it includes.

- Two known resistance (R_1 and R_2)
- One variable resistor (R_3)
- One resistor representing the strain gauge. (R_4)

The bridge is excited by an input voltage Vex, and the output voltage Vo is measured between the 2 midpoints of the bridge.

When strain is applied to the strain gauge, its Resistance (R_4) changes. This causes the bridge to become unbalanced, resulting in a non-zero output voltage Vo. The output voltage Vo is proportional to the change in resistance of the strain gauge, which is proportional to the strain experienced by the gauge.

At $x = 10.2$cm

Weight (g)	Trial 1 $\times 10^{-3}$ V	Trial 2 $\times 10^{-3}$ V	Trial 3 $\times 10^{-3}$ V	Average(V0) $\times 10^{-3}$ V	$\varepsilon = V_0/G_f V_{ex}$ $\times 10^{-6}$	m/ε (g) $\times 10^6$
0	0	0	0	0	0	—
50	0.11	0.11	0.11	0.11	23.78	2.102
100	0.21	0.21	0.21	0.21	45.40	2.20
150	0.30	0.30	0.30	0.30	64.86	2.31
200	0.40	0.40	0.40	0.40	86.48	2.31
250	0.50	0.50	0.50	0.50	108.108	2.31
300	0.60	0.60	0.60	0.60	129.72	2.31

Mean $m/\varepsilon = 2.257 \times 10^6$

Young's modulus $Y = \dfrac{3mgx}{bt^2 \varepsilon}$

$$= \frac{3 \times 980 \times 10.2}{2.67\,(0.20)^2} \times 2.257 \times 10^6$$

$$= 6.337 \times 10^{11}\ \text{dyne/cm}^2$$

The relationship between the output voltage, gauge factor and strain is given by equation (3).

ie.

$$\varepsilon = \frac{V_0}{G_f \cdot V_{ex}} \qquad (3)$$

The young's modulus (Y) is a measure of the stiffness of a material. It is defined as the ratio of stress (σ) to strain (ε)

$$Y = \frac{\sigma}{\varepsilon} \qquad (4)$$

For a cantilever beam subjected to a load F at it's free end, the stress is given by:

$$\sigma = \frac{6Fx}{bt^2} \qquad (5)$$

where,

F – Applied load (force)

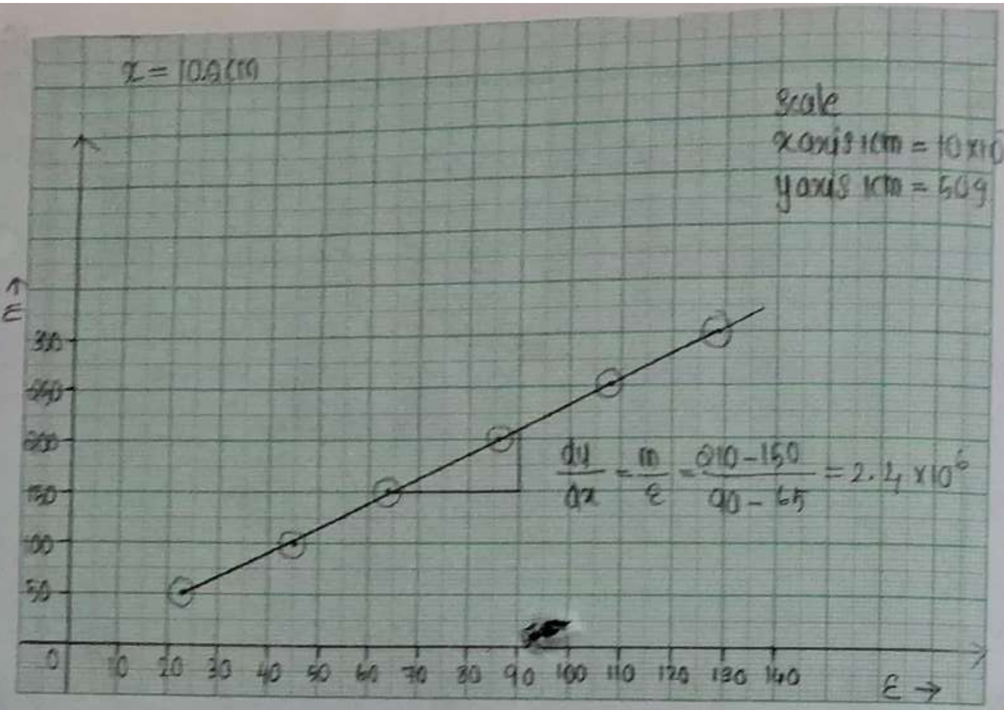
x – Distance between the point at which force acting to the centre of strain gauge

b – Breadth of the cantilever beam

t – Thickness of the cantilever beam.

By combining the equations for stress and strain from (3) and (5), young's modulus can be determined as

$$Y = \frac{6Fx}{bt^2 \varepsilon} = \frac{6Fx\, G_f \cdot V_{ex}}{bt^2 \cdot V_0} \qquad (6)$$



From graph

$\frac{m}{\varepsilon} = 2.4 \times 10^{6}\,g$

$y = \frac{3gx}{bt^2} \times \frac{m}{\varepsilon} = \frac{3 \times 980 \times 10.2}{2.67\,(0.20)^2} \times 2.4 \times 10^{6}$

$= \underline{6.738 \times 10^{11}\ \text{dynes/cm}^2}$

mean value of $y = \frac{[6.337 \times 10^{11}] + [6.738 \times 10^{11}]}{2}$

$= \underline{6.538 \times 10^{11}\ \text{dynes/cm}^2}$

In the strict bending stress derivation, the coefficient 6 is accurate, but in some contexts, particularly in educational simplifications or specific engineering practice the strain might be averaged over certain distances and reducing the factor 6 in to 3

Therefore,
The young's modulus of cantilever beam is given reduced to,

$$Y = \frac{3Fx}{bt^2\varepsilon} = \frac{3mgx}{bt^2\varepsilon} \quad (7)$$

where,
g - Acceleration due to gravity
m - mass of the load

PROCEDURE

1 - Set up the cantilever beam in the loading arrangement, fixing one end securely. The arrangement includes a strain voltage indicator which is adjusted to zero first.
2 - The breadth and thickness of the cantilever measured using vernier calipers/screw gauge and the distance between the point at which the load is applying and the centre of strain gauge is measured using a meter scale.
3 - The excitation voltage Vex and gauge factor GF given on the strain gauge is noted.

The value of young's modulus,

At $x = 9$ cm,

$$Y = 6.562 \times 10^{11} \text{ dyne/cm}^2$$

At $x = 10.2$ cm,

$$Y = 6.538 \times 10^{11} \text{ dyne/cm}^2$$

$$\text{mean } Y = \frac{[6.562 \times 10^{11}] + [6.538 \times 10^{11}]}{2}$$

$$= \underline{\underline{6.55 \times 10^{11} \text{ dynes/cm}^2}}$$

The standard value of young's modulus of Aluminium cantilever is

$$Y = 69 \text{ Gpa} = 6.9 \times 10^{11} \text{ dyne/cm}^2$$

$$\text{The error percentage} = \frac{[6.9 \times 10^{11}] - [6.55 \times 10^{11}]}{[6.9 \times 10^{11}]} \times 100$$

$$= \underline{\underline{5.0\%}}$$

4 - Gradually apply known weights at the free end of the beam to create a point load (F).

5 - For each applied load (F), record the corresponding output voltage from the strain gauge.

6 - Record the corresponding strain (ε) readings from the output voltage, V_o, for each applied load, using gauge factor and excitation voltage by equation (3)

7 - Calculate the ratio between each applied load and strain, that is m/ε

8 - Using equation (7),

$$Y = \frac{3mgx}{bt^2 \varepsilon}$$

Calculate the young's modulus of cantilever

9 - The experiment is repeated for different x values.

10 - Plot a graph between m and ε, where m is along y axis and ε along x axis. The slope of the curve give m/ε. By substituting this value in (7), we can determine young's modulus from graph.

RESULT

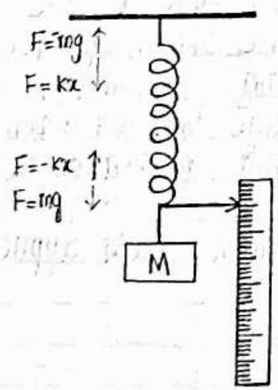
The young's modulus of Aluminum cantilever,

$$Y = \underline{\underline{6.55 \times 10^{11} \text{ dyne/cm}^2}}$$

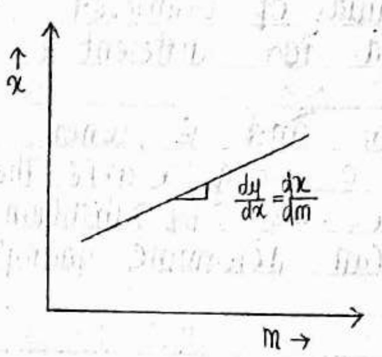
Error percentage $= \underline{\underline{5.0\%}}$

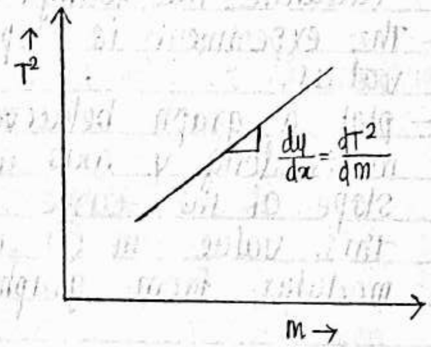
5/7/24

DIAGRAM



EXPECTED GRAPHS





Mass of the Spring $= \underline{44g}$

Effective mass $M_s = M_d = \frac{1}{3} \times 44 = \underline{14.6g}$

Actual length of the Spring = 24 cm

EXPERIMENT 3 DATE - 6/2/2024

SPRING CONSTANT - STATIC AND DYNAMIC METHOD

AIM

To determine the force constant of a spring by

① Static method.
② Dynamic method.

APPARATUS REQUIRED

Helical spring attached to a stand, slotted weights, metre scale and stop watch.

THEORY

A Spring is an elastic object which stores mechanical energy. The spring constant K of an ideal spring is defined as the force per unit length and is different from one spring to another. Spring consta[nt] is represented in Newton/meter (N/m). It can be determined both in static as well as dynamic conditions. Two different techniques are used for determination of the spring constant. In the static method, Newton's II law of motion is used for the equilibrium case, and laws of periodic motion are applied for determining the spring constant in

STATIC METHOD

OBSERVATION AND CALCULATION

Load $\times 10^{-3}$ kg	Position of pointer Loading $\times 10^{-2}$ m	Position of pointer unloading $\times 10^{-2}$ m	Average $\times 10^{-2}$ m	shift for sucessive weight (x) $x = x_n - x_0$ $\times 10^{-2}$ m	F=mg (N)	$K_s = \frac{F}{x}$ (N/m)
0+14.6	23.7	23.6	23.65	0		
500+14.6	24.7	25.2	24.95	1.3	4.9	376.92
1000+14.6	27.2	27.2	27.2	3.55	9.8	276.06
1500+14.6	29.9	30.1	30	6.35	14.7	231.49
2000+14.6	32.8	33	32.9	9.25	19.6	211.89
2500+14.6	35.8	36	35.9	12.25	24.5	200.00
3000+14.6	38.7	38.7	38.7	15.05	29.4	195.34

$$\text{Mean } K_s = \frac{276.06+231.49+211.89+200.00+195.34}{5}$$

$$= \underline{\underline{222.95 \text{ N/m}}}$$

From graph

$$\frac{dy}{dx} = \frac{dx}{dm} = \frac{(8.7-7.5)\times 10^{-2}}{(1.9-1.675)} = \frac{0.012}{0.225} = \underline{\underline{0.053}}$$

$$\frac{dm}{dx} = \frac{1}{0.053} = \underline{\underline{18.87}}$$

$$K_s = \frac{dm}{dx} \times g = 18.87 \times 9.8 = \underline{\underline{185 \text{ N/m}}}$$

the dynamic case.

(1) Static method

In this method of determination of spring constant, a weight is added to the spring and it's extension is measured. The spring is fixed at one end and a weight is added in equal amounts one by one. After adding a weight the spring will attain a stationary position after some time. At equilibrium, there are two equal and opposite forces, acting upward and downward

In equilibrium condition,

upward force = Downward force

$F_{up} = F_{down}$

According to Hook's law, the restoring force.

$$F_{up} = -K_s x \quad \text{or} \quad F_{up} = Kx \qquad (1)$$

where, K_s is the spring constant. The negative sign indicates a restoring force, that is, the force that allows the object to return to its original shape and position.

$$F_{down} = mg \qquad (2)$$

Equating (1) and (2), we get

Error percentage $= \frac{222.95 - 185}{222.95} \times 100$

$= \underline{\underline{17\%}}$

$$K_s x = mg$$

$$K_s = \frac{mg}{x} \quad (3)$$

where,

m – Mass of the load applied.
g – Acceleration due to gravity.
K_s – spring constant in the static condition.
x – Displacement of the spring from it's equilibrium position.

However, the spring has a finite mass, denoted by M_s, which adds to the load, hence m in equation ③ is replaced by $(m+M_s)$, giving

$$K_s = \frac{(m+M_s)g}{x} \quad (4)$$

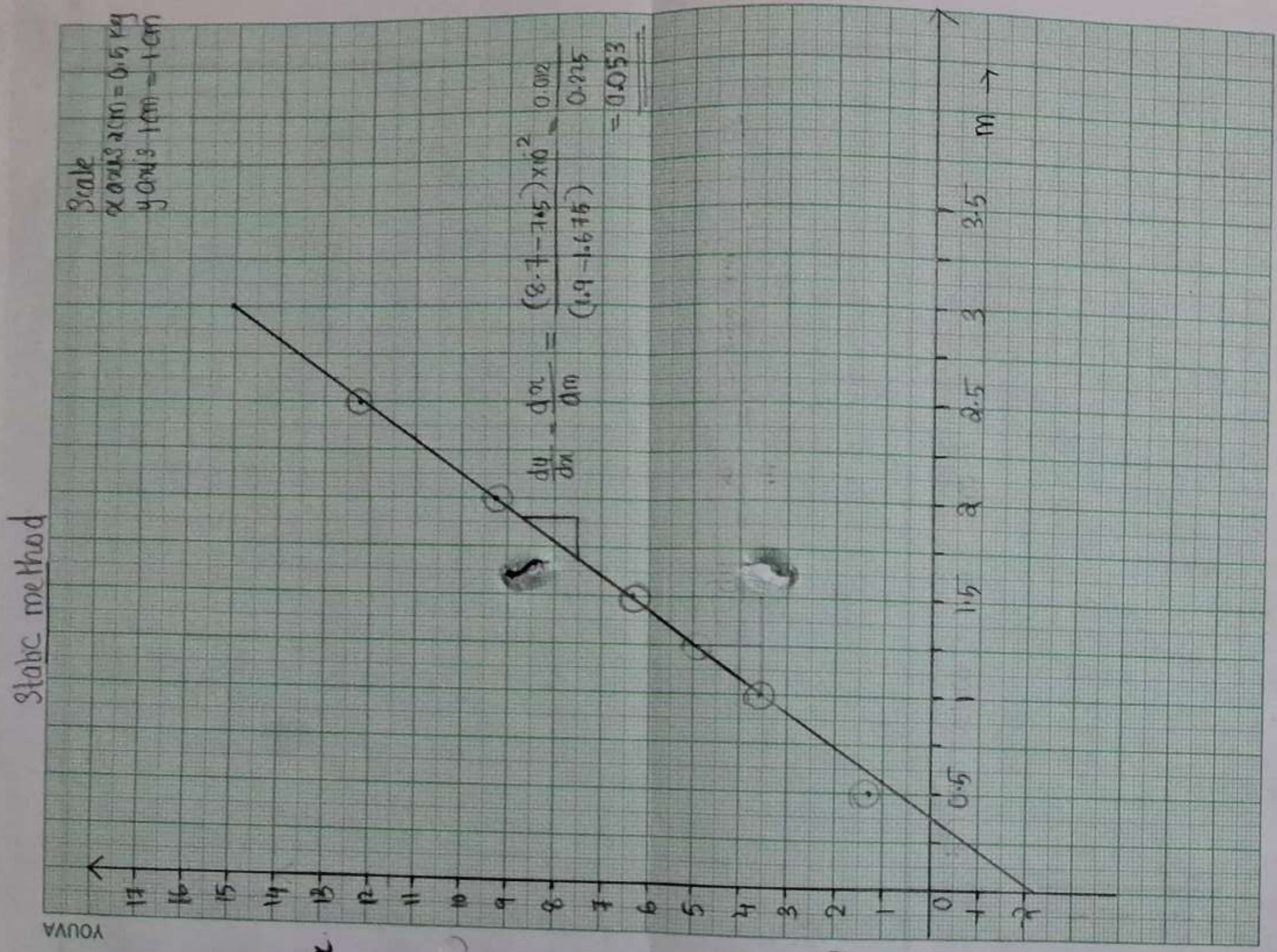
② Dynamic method

If the spring is made to oscillate by pulling the weight applied to it downward, it executes a simple harmonic motion. The equation representing it's motion is written as

$$\frac{d^2y}{dx^2} = \frac{Ky}{m} \quad (5)$$

The angular velocity is given by,

$$\omega = \sqrt{\frac{K}{m}} \quad (6)$$



Error percentage $= \frac{222.95-185}{222.95} \times 100$

$= \underline{\underline{17\%}}$

$= mg$

$= \frac{mg}{x}$ (3)

ass of the load applied.
cceleration due to gravity.
spring constant in the static condition.
isplacement of the spring from it's equilibri-
m position.

spring has a finite mass, denoted by
is to the load, hence m in equation
by $(m+M_s)$, giving

$= \frac{(m+M_s)g}{x}$ (4)

method

ng is made to oscillate by pulling the
ed to it downward, it executes a
onic motion. The equation representing
s written as

$$\frac{d^2y}{dx^2} = \frac{ky}{m} \quad (5)$$

The angular velocity is given by,

$$\omega = \sqrt{\frac{k}{m}} \quad (6)$$

DYNAMIC METHOD

OBSERVATION AND CALCULATION

Load $m+M_d$ $\times 10^{-3}$ kg	Time for 20 Oscillations 1 (s)	Time for 20 Oscillations 2 (s)	Average t (s)	$T = t/20$ (s)	T^2 s^2	$K_d = \frac{4\pi^2(m+M_d)}{T^2}$ N/m
500+14.6	6.61	6.97	6.79	0.3395	0.115	176.47
1000+14.6	8.84	9.26	9.05	0.4525	0.204	196.14
1500+14.6	11.75	11.72	11.74	0.5870	0.345	173.14
2000+14.6	13.88	13.23	13.55	0.6775	0.46	172.72
2500+14.6	15.29	15.25	15.27	0.7635	0.60	165.28
3000+14.6	15.82	16.27	16.05	0.8030	0.645	184.32

Mean $K_d = \frac{176.47+196.14+173.14+172.72+165.28+184.32}{6}$

$= \underline{178.01}$ N/m

From graph

$\frac{dy}{dx} = \frac{dT^2}{dm} = \frac{0.25-0.17}{1.1396-0.7896} = \underline{\underline{0.228}}$

$\frac{dm}{dT^2} = \frac{1}{0.228} = 4.385$

$K_d = 4\pi^2 \frac{dm}{dT^2} = 4\times(3.14)^2 \times 4.385 = \underline{\underline{172.93}}$ N/m

Therefore, the time period of the oscillation of the spring is,

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K}}$$

If the dynamic spring has an effective mass Md, then it's time period is,

$$T = 2\pi\sqrt{\frac{m+M_d}{K_d}}$$

$$K_d = \frac{4\pi^2(m+M_d)}{T^2} \quad (7)$$

where,

m – Mass of the weight hanging
Md – Effective dynamic mass of the spring
T – Time period of oscillation
Kd – Spring constant in the dynamic condition.

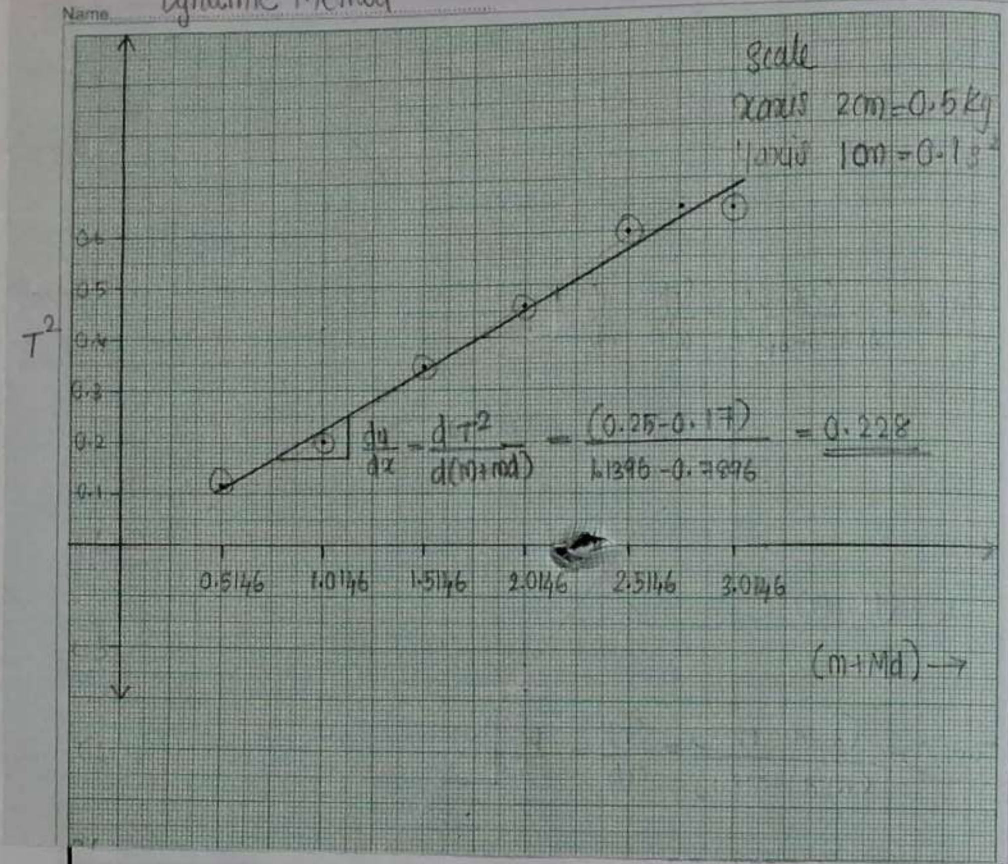
Effective masses in two methods can be eliminated by considering the shift corresponding to successive weight

PROCEDURE

Static method

1 – Attach a spring vertically to a stand and set measuring scale close to spring vertically

Name Dynamic Method Date



$$\text{Error percentage} = \frac{178.01-172.93}{178.01} \times 100$$

$$= 2.85\%$$

2 - Measure the equilibrium position of the spring without any mass, x_0
3 - Hang the weight on the end of the spring one by one in equal amounts and measure new equilibrium positions, x_n
4 - Repeat the process of measuring equilibrium positions on unloading.
5 - Take average of the extension length on loading and unloading.
6 - Determine the displacement caused by the mass
7 - Using Hooke's Law, calculate the Spring constant in Static condition. (equation ④)

Dynamic method

1 - Attach a spring vertically to a stand
2 - Hang a weight 'm' from the spring
3 - Displace the mass slightly by pulling it from it's equilibrium position and release it, allowing it to Oscillate.
4 - Use a stopwatch to measure the time for 20 Oscillations
5 - Repeat the process two times and calculate the average period (T) by dividing the total time by the number of oscillations.
6 - Using the simple harmonic motion equation ⑦, calculate the dynamic spring constant for the spring.

RESULT

By static method

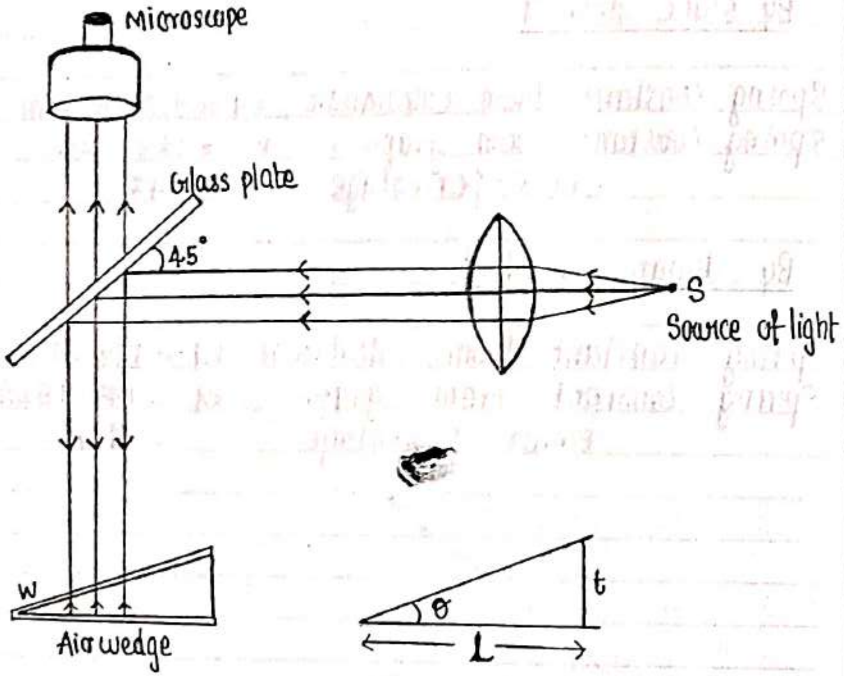
Spring constant from calculation , kd = 222.95 N/m
Spring constant from graph , ks = 185 N/m
Error percentage = 17%

By dynamic method

Spring constant from calculation , kd = 178.01 N/m
Spring constant from graph , kd = 172.93 N/m
Error percentage = 2.85%

5/7/24

DIAGRAM



Least count of travelling microscope $LC = 0.001 \, cm$

wavelength of monochromatic light (sodium lamp) $= 589 \times 10^{-9} m$

EXPERIMENT 4 DATE - 6/2/2024

COMPARISON OF THICKNESS OF THIN SHEETS BY AIR WEDGE

AIM

To determine the thickness of different thin sheets and compare with each other.

APPARATUS REQUIRED

Air wedge, Travelling microscope, sodium vapour lamp, Reading lens, Thin sheets, plane glass plate.

THEORY

When a piece of thin paper is introduced between two parallel transparent polished glass plates, a wedge of air is trapped between the two glass plates. When monochromatic light is incident on this arrangement, it undergoes multiple reflections between the two glass plates leading to an interference pattern, of alternating bright and dark fringes.

Constructive interference occurs when the path difference between the two reflected waves is an integer multiple of the wavelength $(n\lambda)$. This results in bright fringes.

Destructive interference occurs when the path difference is an odd multiple of half wavelength

OBSERVATIONS AND CALCULATION

To determine the thickness of sheet 1

$L = 5.8 \times 10^{-2}$ m   LC = 0.001 cm

Order	Microscope reading MSR cm	Microscope reading VSR cm	Total reading MSR+(VSR×LC) cm	Width of 10 bands cm
2	7.05	9	7.059	
4	7.05	13	7.063	
6	7.10	40	7.140	
8	7.15	25	7.175	
10	7.20	0	7.200	
12	7.20	32	7.232	0.173
14	7.25	1	7.251	0.188
16	7.25	12	7.262	0.122
18	7.30	29	7.329	0.154
20	7.35	2	7.352	0.152

Mean width of 10 bands $= 0.1578 \times 10^{-2}$ m

Bandwidth $\beta = \dfrac{\text{Total width of 10 bands}}{10} = \dfrac{0.1578 \times 10^{-2}}{10} = \underline{0.1578 \times 10^{-3} \text{ m}}$

$\beta = 0.1578 \times 10^{-3}$ m

$\lambda = 589 \times 10^{-9}$ m

$L = 5.8 \times 10^{-2}$ m

Thickness of sheet 1, $t_1 = \dfrac{\lambda L}{2\beta} = \dfrac{589 \times 10^{-9} \times 5.8 \times 10^{-2}}{2 \times 0.1578 \times 10^{-3}}$

$= \underline{\underline{1.0824 \times 10^{-4} \text{ m}}}$

$\left((2n+1)\dfrac{\lambda}{2}\right)$. This results in dark fringes.

The path difference between the two reflected rays is given by

$$\Delta = 2t \qquad (1)$$

where t is the thickness of the air wedge at a given point.

For constructive interference,

$$2t = n\lambda, \quad n = 0, 1, 2, 3 \ldots \qquad (2)$$

For destructive interference,

$$2t = \left(n + \tfrac{1}{2}\right)\lambda, \quad n = 0, 1, 2, 3 \ldots \qquad (3)$$

For an air wedge of angle 'θ' as in the figure,

$$\tan\theta = \frac{t}{L} \qquad (4)$$

$$t = L \tan\theta$$

The thickness of the air wedge at a distance 'x' from the edge is,

$$t = x \tan\theta \qquad (5)$$

For constructive interference at point x,

$$2t = n\lambda$$

To determine the thickness of sheet 2

$L = 6.2 \times 10^{-2}$ m $\qquad$ LC = 0.001 cm

Order	Microscope reading		Total reading	width of 10 bands
	MSR cm	VSR cm	MSR+(VSR×LC) cm	cm
2	6.95	0	6.950	
4	7.00	45	7.045	
6	7.00	10	7.010	
8	7.05	17	7.067	
10	7.10	43	7.143	
12	7.10	40	7.140	0.190
14	7.15	24	[illegible]174	0.130
16	7.20	18	7.218	0.208
18	7.20	10	7.210	0.143
20	7.25	30	7.280	0.137

Mean width of 10 bands $= 0.1616 \times 10^{-2}$ m

Band width, $\beta = \dfrac{\text{Total width of 10 bands}}{10} = \dfrac{0.1616 \times 10^{-2}}{10} = \underline{\underline{0.1616 \times 10^{-3} \text{ m}}}$

$\beta = 0.1616 \times 10^{-3}$ m
$\lambda = 589 \times 10^{-9}$ m
$L = 6.2 \times 10^{-2}$ m

Thickness of sheet 2, $t_2 = \dfrac{\lambda L}{2\beta} = \dfrac{589 \times 10^{-9} \times 6.2 \times 10^{-2}}{2 \times 0.1616 \times 10^{-3}}$

$= \underline{\underline{1.13 \times 10^{-4} \text{ m}}}$

$\therefore \quad 2x \tan\theta = n\lambda \qquad (6)$

For x corresponding to the nth fringe,

$2x_n \tan\theta = n\lambda \qquad (7)$

When the angle θ is very very small, then

$\tan\theta \approx \theta$.

And using the geometry of the wedge,

$\theta \approx \dfrac{t}{L}$

Then equation (7) becomes,

$2x_n \theta = n\lambda$

$2x_n \dfrac{t}{L} = n\lambda$

$x_n = \dfrac{n\lambda L}{2t} \qquad (8)$

The fringe width or band width 'β' in the interference pattern is the distance between two consecutive bright or dark fringes,

$\beta = x_{n+1} - x_n$

$= \dfrac{(n+1)\lambda L}{2t} - \dfrac{n\lambda L}{2t}$

$\beta = \dfrac{\lambda L}{2t} \qquad (9)$

$\therefore$ The thickness, $t = \frac{\lambda L}{2\beta}$

where,

λ – wavelength of the light used

L – Length of the airwedge, the distance over which the plates are separated

β – Fringe width

t – thickness of the airwedge

PROCEDURE

1 – place a thin sheet, whose thickness is to be measured between two glass plates to form an air wedge. The thin sheet is placed at one end or near to the end. The other end of the plates is held tight by a rubber band so that it becomes the line of contact. Measure the length (L) of airwedge.

2 – Switch on the sodium vapour lamp.

3 – A wooden box provided with glass plate inclined at 45° and the monochromatic light from the sodium vapour lamp is allowed to fall on this glassplate

4 – Place the air wedge inside the wooden box such that the reflected light from the glass plate is incident normally on the air wedge.

5 – Adjust the travelling microscope which is placed vertically above the inclined glass plate and airwedge to view interference band clearly. Focus the cross wires exactly.

6 – Measure the distance corresponding to 20 bright or dark fringes using the travelling microscope.

7- Width of 10 fringes deduced and the fringe width (β) is calculated by dividing the measured distance on the number of fringes. The measurements are recorded in a suitable table

8- Using the formula,

$$t = \frac{\lambda L}{2\beta}$$

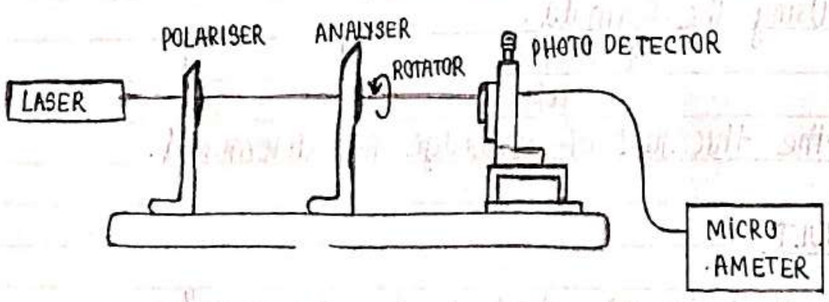
the thickness of airwedge is determined.

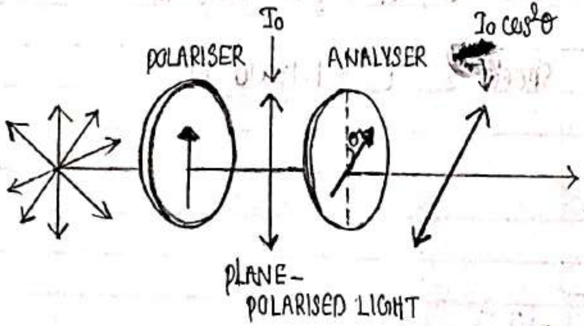
RESULT

The thickness of sheet 1, $t_1 = \underline{1.0824 \times 10^{-4}}$ m

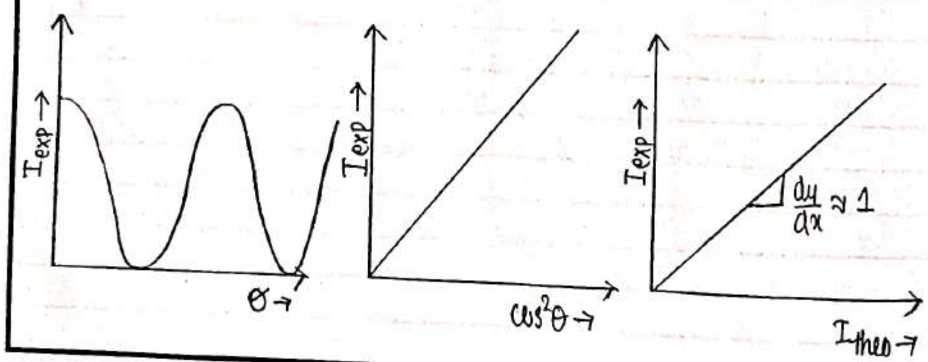
The thickness of sheet 2, $t_2 = \underline{1.13 \times 10^{-4}}$ m

5/7/24





EXPECTED GRAPHS



EXPERIMENT 5 DATE - 8|2|2024

MALUS LAW - VERIFICATION

AIM

To determine the relationship between the intensity of the transmitted light through analyser and 'θ', the angle between the axes of polarizer and analyzer and to verify Malus law.

APPARATUS REQUIRED

A diode laser, a polarizer - analyzer pair, photo detector, detector output measuring unit (μA) and an optical bench

THEORY

The light coming from the sun, candle light, and light emitted by a bulb is an ordinary light and is known to be un-polarized. In an un polarized light electric and magnetic field vectors vibrate in all possible directions perpendicular to each other and also perpendicular to the direction of propagation of light. When an un polarized light falls on a polarizer, the transmitted light gets polarized. The polarized light falling on another polaroid called analyzer, transmits light depending on the orientation of its axis with the polarizer.

OBSERVATION AND CALCULATION

Angle of analyzer when current is maximum, $\phi_0 = 60^\circ$

Maximum current, $I_{max} = 1\ \mu A$

Angle of analyzer ϕ [degrees]	Angle between the axes of polarizer and analyzer $\theta = \phi - \phi_0$ [degrees]	$\cos\theta$	$\cos^2\theta$	Current = intensity I_{expt} (μA)	$I_{theo} = I_{max} \times \cos^2\theta$ (μA)
0	-60	0.5	0.25	0.1	0.25
10	-50	0.64	0.41	0.3	0.41
20	-40	0.77	0.60	0.5	0.60
30	-30	0.87	0.76	0.7	0.76
40	-20	0.94	0.88	0.8	0.88
50	-10	0.98	0.96	0.9	0.96
60	0	1	1	1	1
70	10	0.98	0.96	0.9	0.96
80	20	0.94	0.88	0.8	0.88
90	30	0.87	0.76	0.7	0.76
100	40	0.77	0.60	0.5	0.60
110	50	0.64	0.41	0.3	0.41
120	60	0.5	0.25	0.1	0.25
130	70	0.34	0.12	0	0.12
140	80	0.17	0.03	0.1	0.03
150	90	0	0	0	0
160	100	-0.17	0.03	0	0.03
170	110	-0.34	0.12	0	0.12

Malus's law states that when a completely plane polarized light is incident on the analyzer, the intensity (I) of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer.

$$I \propto \cos^2\theta$$

If A_0 is the amplitude of the incident light and A_t is amplitude of the light transmitted through the analyzer, which in inclined at an angle θ with the polarizer then,

$$A_t = A_0 \cos\theta$$

As, intensity $\propto$ (amplitude)^2

$$I_t = A_t^2 = A_0^2 \cos^2\theta = I_0 \cos^2\theta$$

where,

I_t – Intensity of light transmitted through analyzer.

I_0 – Intensity of incident plane polarized light.

θ – Angle between axis of polarizer and analyzer.

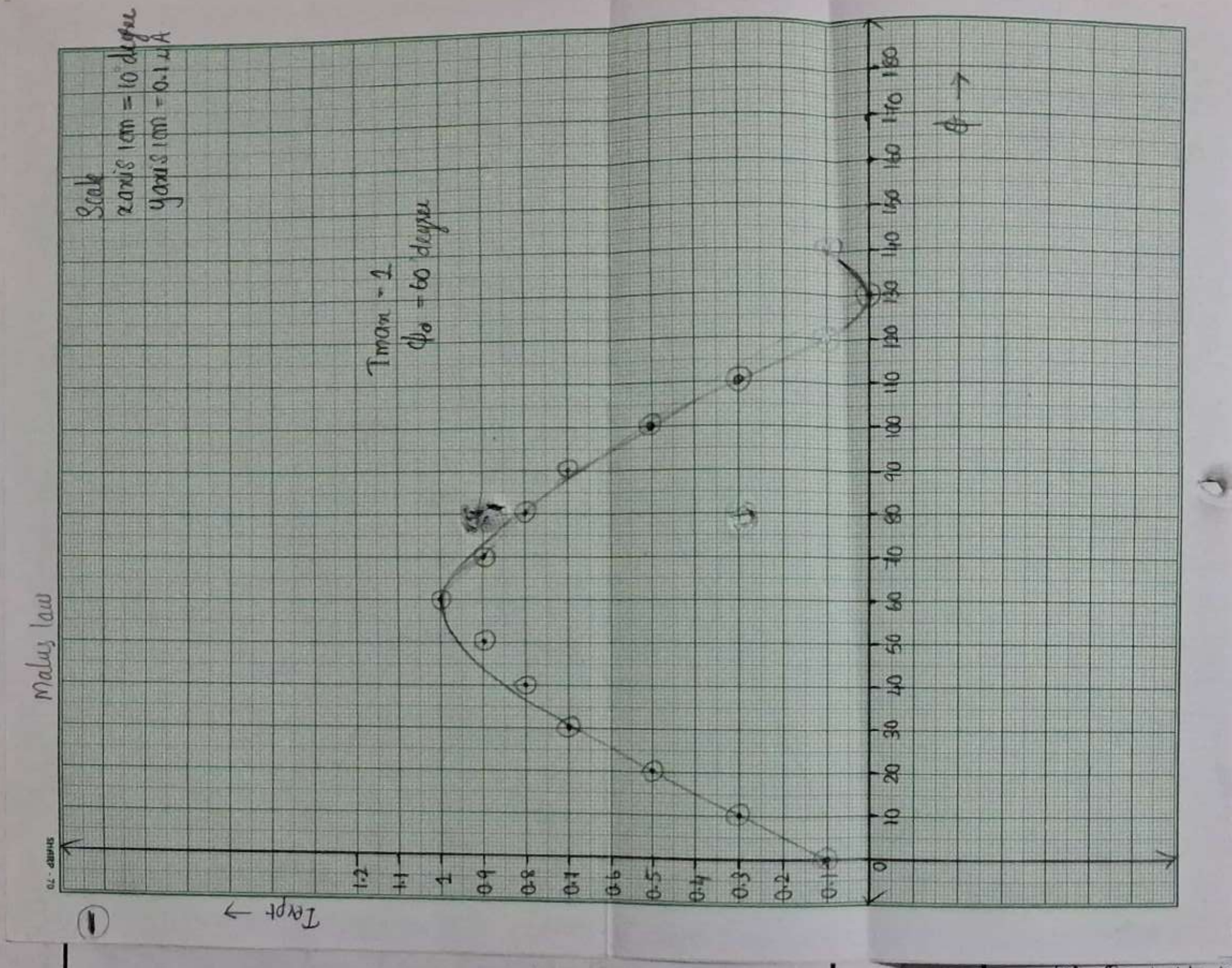
$$I_{theo} = I_{max} \cos^2\theta$$

PROCEDURE

1 – set up the laser, photodiode, the polarizer and analyser as shown in figure. Align the polarizer and analyzer so that their transmission axes are parallel.
2 – Keep the polarizer fixed and rotate the analyzer until you observe a maximum in transmission. Note down maximum current I_{max} and angle as ϕ_0. If it is difficult to find the maximum intensity, plot a graph between I_{exp} and ϕ, which is the angle of analyzer and obtain the angle corresponding to maximum current.
3 – Rotate the analyzer in 10° increments
4 – For each angle ϕ, measure the transmitted light intensity I_{exp} using the photodetector.
5 – By subtracting ϕ_0, the angle corresponding to maximum intensity from ϕ, θ can be find, which is the angle between the axes of polarizer and analyzer.
6 – Theoretical value of intensity can be find using the expression

$$I_{theo} = I_{max} \cos^2\theta$$

7 – Verifying malus law by plotting graph between
① I_{expt} Vs θ, I_{expt} in y axis and θ in x axis
② I_{expt} Vs $\cos^2\theta$, I_{expt} in y axis and $\cos^2\theta$ in x axis
③ I_{expt} Vs I_{theo}, I_{expt} in y axis and I_{thu} in x axis



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$= I_{max} \cos^2\theta$

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θ, Iexpt in y axis and θ in x axis
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(3) Iexpt Vs Itheo, Iexpt in y axis and Itheo in x axis

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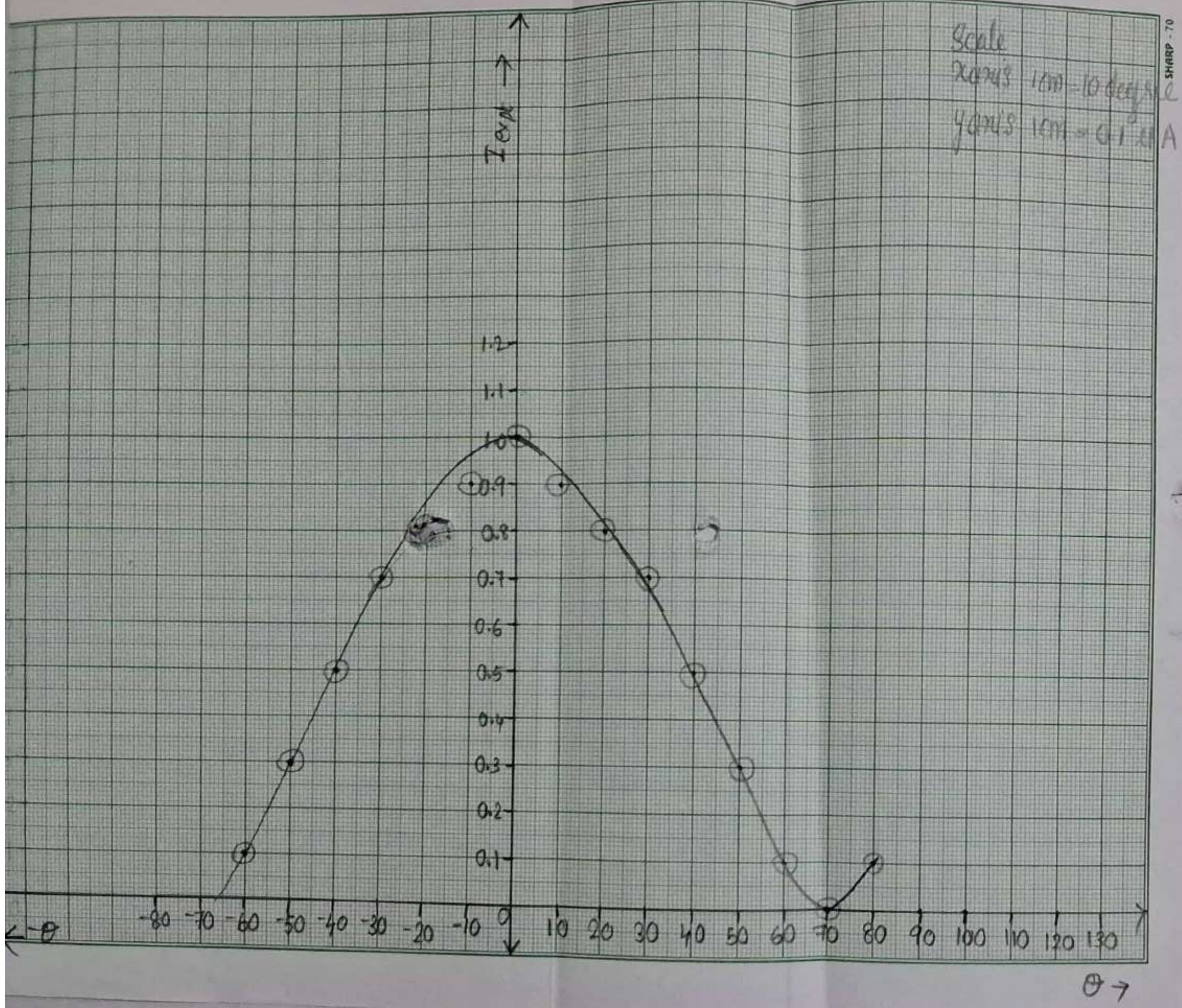

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alus law by plotting graph between
θ, Iexpt in y axis and θ in x axis
(2) Iexpt Vs $\cos^2\theta$, Iexpt in y axis and $\cos^2\theta$ in x axis
(3) Iexpt Vs Itheo, Iexpt in y axis and Itheo in x axis

RESULT

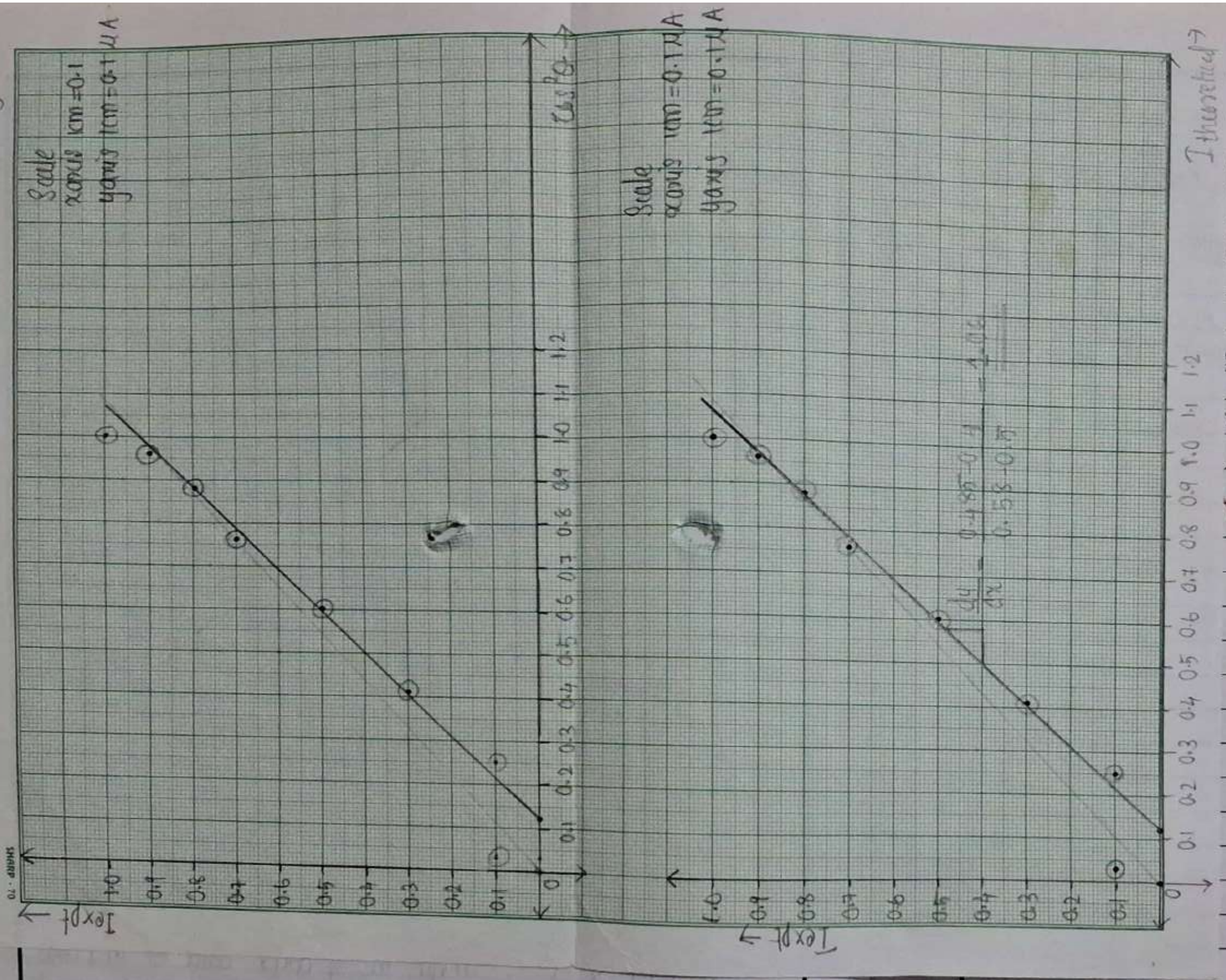
Malus law verified from the experimental data.

The slope of straight line in graph I_{expt} Vs I_{theo} is calculated.

slope $= 1.06 \simeq 1$

unit slope indicating the correctness of Malu's law.

I_{exp} Vs θ , I_{exp} Vs $\cos^2\theta$ has been plotted.



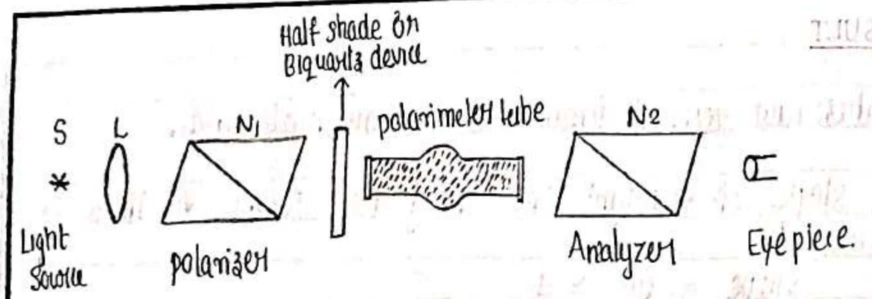
rom the experimental data.

t line in graph Iexpt Vs Itheo is

≃ 1

the correctness of Malu's law.

Vs $\cos^2\theta$ has been plotted.



EXPERIMENT 6 DATE – 15/3/2024

OPTICAL ACTIVITY – SPECIFIC ROTATION MEASUREMENT

AIM

Using half shade polarimeter, Rotation (θ) versus concentration (c) curve to be drawn and to find specific rotation of sugar solution and compare with the standard value.

APPARATUS REQUIRED

Source of light (sodium lamp for half-shade polarimeter), polarimeter, glass beaker, water, sugar, digital balance

THEORY

A polarimeter consists of two Nicols termed as polarizer and analyzer. These can be rotated about a common axis and the substance for which the rotation is to be determined, is placed in a tube in between these two. The half shade plate is placed between the polarizer and the solution tube.

The polarizer is a circular plate with two halves. One half is made of quartz cut parallel to its optic axis, and is thick enough to create a half-wavelength delay for sodium light. The other half is made of glass, matched in thickness so that

OBSERVATION AND CALCULATIONS

Least count $= \frac{1^\circ}{10} = 0.1$

$L = 0.1 \times 20 = 2$ dm

Concentration g/ml (C)	Polarimeter reading in degree MSR	VSR	MSR+(VSR×LC)	Angle of rotat^n in degree (θ)	Specific rotation $\alpha = \frac{\theta}{LC}$ $^\circ(g/ml)^{-1}(dm)^{-1}$
0	188	5	188.5	0	
0.05	195	8	195.8	7.3	73
0.1	200	1	200.1	11.6	58
0.15	206	7	206.7	18.2	75.8
0.2	215	2	215.2	26.7	66.75

Mean Specific rotation $= 68.38^\circ (g/ml)^{-1} (dm)^{-1}$

Standard value of specific rotation of sucrose $= 66.5^\circ (g/ml)^{-1} (dm)^{-1}$

Error percentage $= \frac{66.5 - 68.38}{66.5} \times 100$

$= 2.82\%$

light passing through it has the same intensity as the light from the quartz. As a result, a plane polarized light beams emerge, one from glass half and one from the quartz half. When these two equal-intensity beams are aligned with the main section of an analyzer, both halves of the field of view seen through the eyepiece will appear equally bright.

When we place a tube of sugar solution between the polarizer and analyzer, it rotates the plane of polarized light. We measure this rotation to understand the optical activity of the sugar solution, which is described by its specific rotation 'α'.

Specific rotation is a measure of how much a substance can rotate the plane of polarized light. It tell us how much the light's direction changes when it passes through a certain amount of the substance in a solution. If the light turns to the right, the substance has a positive specific rotation; if it turns to the left, it has a negative specific rotation.

The specific rotation can be estimated as,

$$\alpha = \frac{\theta}{LC} = \frac{\theta V}{Lm}$$

where, θ - Angle of rotation in degree

L - Path length of the solution (Length of the tube in decimeters

C - Concentration of the solution in g/ml

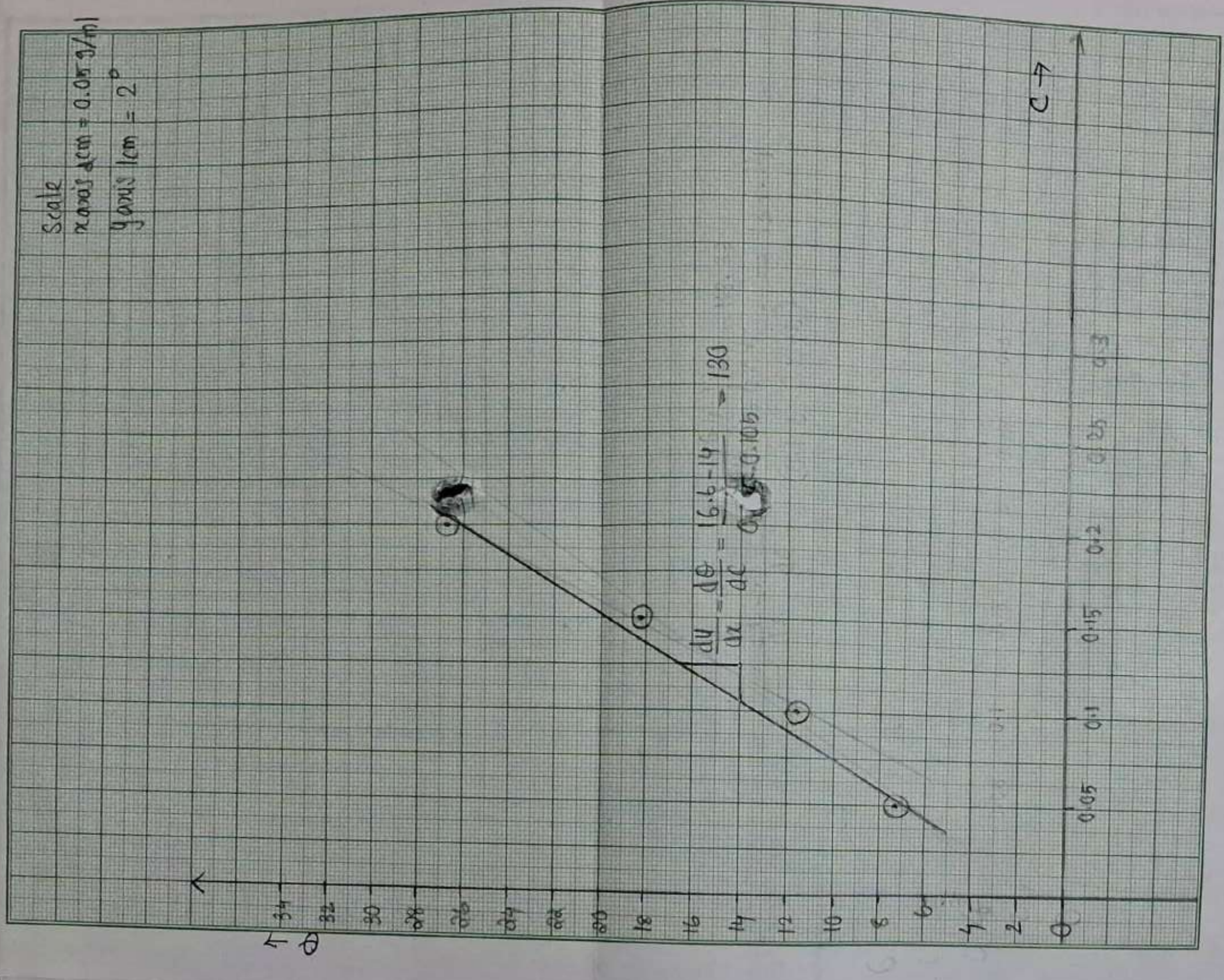
$$C = \frac{m}{V}$$

where, m – Mass of the solute in gram
V – volume of the solution in milliliter.

Specific rotation α can be defined as the angle of rotation (θ) caused by an optically active substance when polarized light passes through a solution of the substance at a specific concentration and path length.

PROCEDURE

1 – Switch on the power of the polarimeter instrument.
2 – illuminate the sodium lamp at maximum emmission. The light will pass through the solution tube.
3 – Fill the sample tube with distilled water, and place the tube in the polarimeter and set the instrument to zero. This step ensures that any rotation observed later is only due to the sugar solution.
4 – Prepare a sugar solution of known concentration by dissolving a known mass of sugar in a known volume of distilled water. In this, we are dissolving 5 grams of sugar in 100 milliliters of water to make a 5% solution
5 – Carefully fill the sample tube with the prepared sugar solution. Ensure there are no air bubbles, as these can affect the accuracy of the measurement.
6 – Place the sample tube in the polarimeter.
7 – Observe and record the angle of rotation 'θ'.



of the solute in gram
e of the solution in milliliter.

can be defined as the angle
caused by an optically active
polarized light passes through a
substance at a specific concentration

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sodium lamp at maximum emmission.
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tube with distilled water, and place
he polarimeter and set the instru.
his step ensures that any rotation
is only due to the sugar solution.
ar solution of known concentration
a known mass of sugar in a known
stilled water. In this, we are dissolving
sugar in 100 milliliters of water
5% solution
the sample tube with the prepared
n. Ensure there are no air bubbles,
as these can affect the accuracy of the
measurement.
6 - Place the sample tube in the polarimeter.
7 - Observe and record the angle of rotation 'θ'.

From graph

$$\frac{dy}{dx} = \frac{d\theta}{dc} = \frac{16.6 - 14}{0.125 - 0.105} = \underline{\underline{130}}$$

Specific rotation $\alpha = \frac{\theta}{lc}$

$$= \frac{1}{L}\frac{d\theta}{dc}$$

$$= \frac{1}{2} \times 130 = 65^\circ (g/mL)^{-1} (dm)^{-1}$$

Error percentage $= \frac{66.5 - 65}{66.5} \times 100$

$= \underline{\underline{2.25\%}}$

this is the angle by which the plane of polarized light is rotated after passing through the sugar solution

8 - using the formula $\alpha = \frac{\theta}{lc}$, calculate the Specific rotation of the sugar solution.

9 - Repeat the experiment by filling 10%, 15% and 20% of solution in sample tube by dissolving 10g, 15g and 20g of sugar in 100 ml of water

10 - Compare the value of specific rotation with it's standard value.

RESULT

The specific rotation of sugar solution $\alpha = 68.38^\circ (g/mL)^{-1} (dm)^{-1}$

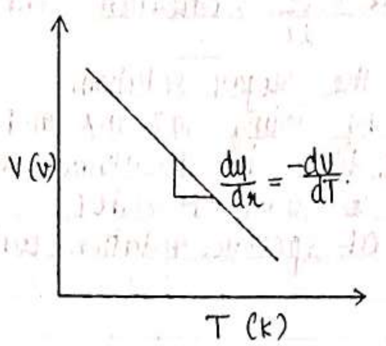
Error percentage $= 2.82\%$

The specific rotation of sugar solution from graph,

$\alpha = 65^\circ (g/mL)^{-1} (dm)^{-1}$

Error percentage $= 2.25\%$

EXPECTED V-T CURVE



EXPERIMENT 7 DATE - 7/5/2024

BANDGAP - SEMICONDUCTOR DIODE

AIM

To determine bandgap energy of silicon diode.

APPARATUS REQUIRED

Silicon diode, Beaker, Thermometer, voltmeter, Ammeter, water, Energy band gap kit

THEORY

The bandgap energy of a semiconductor is a fundamental parameter that defines the energy difference between the valence band and the conduction band. The ideal diode equation provides a basis for experimentally determining the band gap energy through the temperature dependence of the reverse saturation current, which is a small, constant current that flows through a diode when it is reverse biased.

The ideal diode equation describes the current (I) flowing through a diode as a function of the applied voltage (V). It is given by,

$$I = I_0 \left[e^{qV/\eta kT} - 1 \right] \quad (1)$$

where,

OBSERVATIONS AND CALCULATION

$I = 0.150\,mA$ (Kept constant)

$\frac{dV}{dT} = -3.2 \times 10^{-3}\,V/K$ $m = 3$ $\eta = 2$ $q = 1.602 \times 10^{-19}\,C$

Experimental value, $E_g = V - T\frac{dV}{dT} - \frac{m\eta kT}{q}$

Theoretical value, $E_g = 1.17 - \frac{4.73 \times 10^{-4} T^2}{T + 636}$

$k = 8.617 \times 10^{-5}\,eV/K = 1.38 \times 10^{-23}\,J/K$.

Temperature °C	Temperature K	Voltage (V)			Eg (eV)	
		Heating	Cooling	Average	Experimental	Theoretical
35	308	0.435	0.417	0.426	1.252	1.122
40	313	0.419	0.401	0.410	1.249	1.121
45	318	0.401	0.384	0.392	1.245	1.119
50	323	0.380	0.364	0.372	1.238	1.118
55	328	0.358	0.356	0.357	1.237	1.117
60	333	0.334	0.340	0.337	1.230	1.116
65	338	0.315	0.330	0.322	1.228	1.114
70	343	0.297	0.315	0.306	1.226	1.113
75	348	0.279	0.299	0.289	1.222	1.112
80	353	0.265	0.269	0.267	1.214	1.110
85	358	0.248	0.252	0.250	1.210	1.109
90	363	0.232	0.247	0.239	1.213	1.108

Mean theoretical value = 1.115 eV

Mean Experimental value = 1.230 eV

I – The diode current

I_0 – Reverse saturation current

q – charge of the electron = 1.602×10^{-19} C

V – Applied voltage across the diode

η – Ideality factor (typically between 1 and 2 for silicon diodes)

k – Boltzmann constant = 8.61×10^{-5} eV/K

T – Absolute temperature in Kelvin

When the forward voltage (V) across the diode is significantly larger than the thermal voltage $\frac{\eta kT}{q}$,

$$\frac{qV}{\eta kT} \gg 1$$

Then,

$$e^{qV/\eta kT} \gg 1$$

Then equation ① can be reduced to,

$$I = I_0\, e^{qV/\eta kT} \quad (2)$$

The reverse saturation current is usually too small & to be measured directly.

An indirect graphical method may be obtained by taking logarithm of equation ②, we get

$$\ln I = \ln I_0 + \frac{qV}{\eta kT} \quad (3)$$

If V is plotted against lnI a straight line is obtaind

From graph

$$\frac{dy}{dx} = \frac{dV}{dT} = \frac{0.346-0.33}{335-330} = 3.2 \times 10^{-3}\ V/K$$

This line intersects the current lnI axis at Io and it's slope may be solved to find η.

$$\eta = \frac{q}{KT}\frac{\Delta V}{\Delta \ln I}$$

T is the temperature in Kelvin, we can take standard reference temperature as room temperature (300 K)

η decreases as temperature increases. Here we are doing the experiment under constant current and we can take $\eta = 2$ for silicon

The study of the bandgap structure of semiconductors is also important because it is directly proportional to it's electric properties. It has been observed that experimentally, within a certain temperature range, the relation between temperature and voltage is almost linear. This proportionality can be used to determine the band gap.

The reverse saturation current Io for a diode can be expressed as:

$$I_0 = KT^m e^{\frac{-qE_g}{\eta KT}} \quad (4)$$

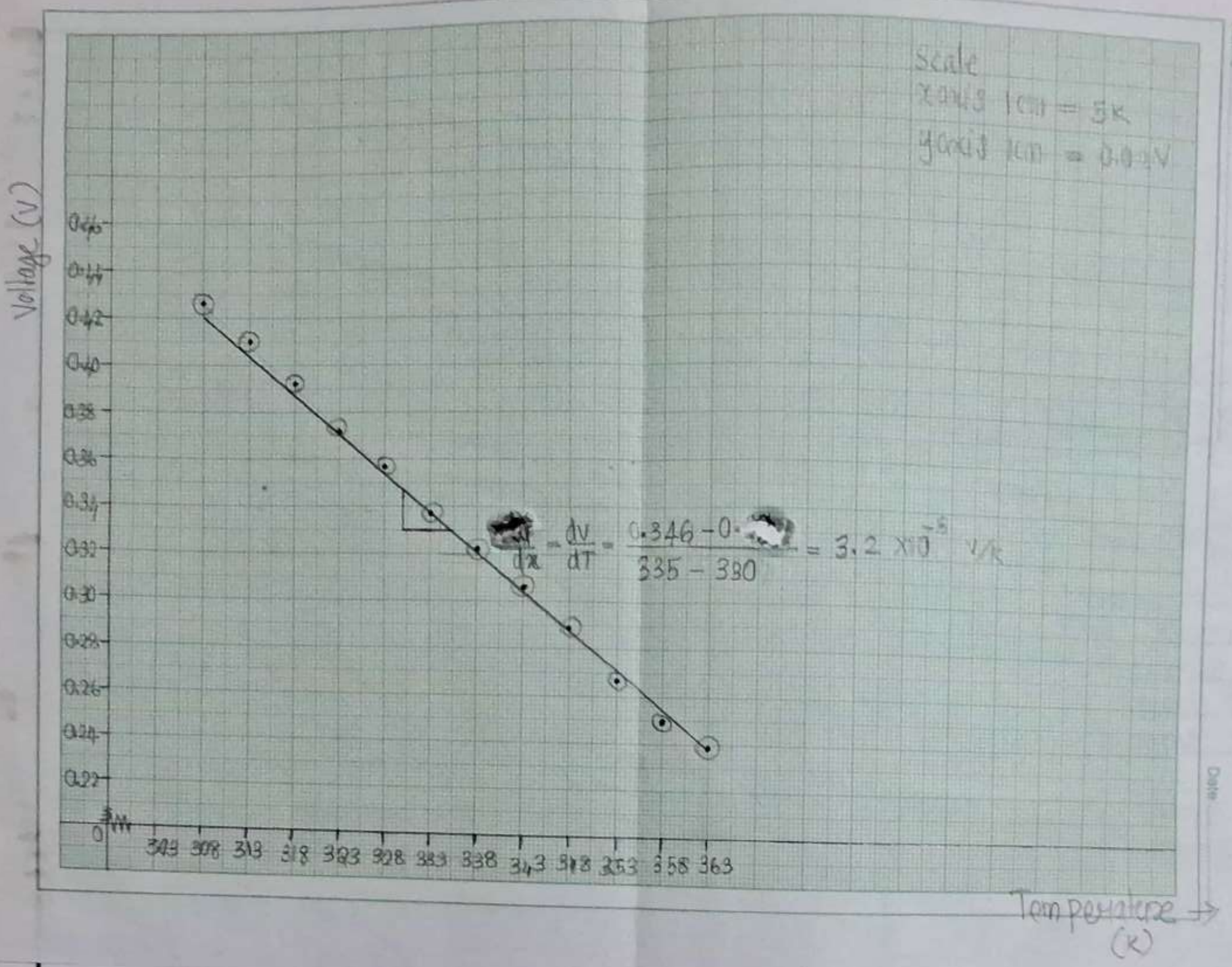
where,

K - constant that depends on the material and geometry of the diode

T - absolute temperature in kelvin.

m - Empirical factor, often close to 3 for silicon

Eg - Energy band gap.



From graph

$$\frac{dy}{dx} = \frac{dV}{dT} = \frac{0.346-0.33}{335-330} = \underline{\underline{3.2 \times 10^{-3}\ V/K}}$$

is the current lnI axis at Io
ay be solved to find n.

$\frac{\Delta V}{\Delta \ln I}$

ture in Kelvin, we can take Standard
ature as room temperature (300 K)

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under constant current and we can
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The bandgap structure of semicondu-
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ration current Io for a diode can
s:

$$KT^{m} e^{-\frac{qE_g}{nkT}} \qquad (4)$$

Where

K – constant that depends on the material and geometry of the diode

T – absolute temperature in kelvin.

m – Empirical factor, often close to 3 for silicon

Eg – Energy band gap.

CALCULATION

Band gap energy at 308 K

Theoretical value $E_g = 1.17 - \frac{4.73\times10^{-4}T^2}{T+636}$

$$= 1.17 - \frac{4.73\times10^{-4}(308)^2}{303+636}$$

$$= \underline{1.122 \text{ eV}}$$

Experimental value $E_g = V - T\frac{dV}{dT} - \frac{m\eta kT}{q}$

$$= 0.426 + [308\times3.2\times10^{-3}] - \left[\frac{3\times2\times1.38\times10^{-23}\times308}{1.602\times10^{-19}}\right]$$

$$= 1.4116 - 0.15919$$

$$= \underline{1.252 \text{ eV}}$$

Error percentage at 308 K $= \frac{1.252 - 1.122}{1.122}\times100$

$$= \underline{11.6\%}$$

we have the diode forward current I, given by

$$I = I_0\, e^{\frac{qV}{\eta kT}}$$

Substitute for I_0 from eq (4)

$$I = KT^m e^{\frac{-qE_g}{\eta kT}} e^{\frac{qV}{\eta kT}}$$

$$= KT^m e^{\left[\frac{qV}{\eta kT} - \frac{qE_g}{\eta kT}\right]}$$

$$= KT^m e^{\frac{q(V-E_g)}{\eta kT}}$$

Take logarithm,

$$\ln I = \ln K + m\ln T + \frac{q(V-E_g)}{\eta kT}$$

At constant current, differentiate the above with respect to T

$$0 = 0 + \frac{m}{T} + \frac{d}{dT}\left[\frac{q(V-E_g)}{\eta kT}\right]$$

$$0 = 0 + \frac{m}{T} + \frac{q}{\eta kT}\frac{dV}{dT} - \frac{q(V-E_g)}{\eta kT^2}$$

Multiply with $\frac{\eta kT^2}{q}$ we get,

$$0 = \frac{\eta kT^{2}}{q}\frac{m}{T} + T\frac{dV}{dT} - (V-E_g)$$

$$E_g = V - T\frac{dV}{dT} - \frac{m\eta kT}{q} \qquad (5)$$

Where, the slope of V-T curve is the temperature coefficient of the junction voltage.

Mean theoretical value, $E_g = 1.115$ eV

Mean Experimental value, $E_g = 1.230$ eV

Error percentage $= \frac{1.23 - 1.115}{1.115} \times 100$

$= \underline{10.3\ \%}$

The junction gradient coefficient α for silicon is typically given in units of eV/K and describes the rate at which the bandgap energy changes with temperature. It is derived from the temperature dependence of the band gap energy using the varshini equation:

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{T+\beta}$$

where,

$E_g(T)$ – The band gap energy at temperature T

$E_g(0)$ – band gap energy at absolute zero temperature

α – Junction gradient coefficient

β – Material specific constant.

For Silicon,

$E_g(0) \simeq 1.17$

$\alpha \simeq 4.73 \times 10^{-4}$ eV/K

$\beta \simeq 636$ K

$$\therefore E_g(T) = 1.17 - \frac{4.73 \times 10^{-4}\, T^2}{T + 636} \quad (6)$$

PROCEDURE

1 – Connect the silicon diode in reverse bias using a power supply.

2 – Take water in a beaker and heat it in burner. It can be used as water bath to study temperature variation.

3 – The Energy band gap kit is provided with probe connecting with diode is diped in the beaker.

4- A thermometer put in a test tube also immersed in water bath

5- A constant current is placed through the diode and the voltage developed across the junction is measured for every 5°C rise in temperature.

6- A graph of V versus T is plotted with temperature along x axis in Kelvin and voltage along y-axis.

7- The slope dv is determined and using equation ⑤, the experimental value of bandgap energy is determined for each temperature and voltage.

8- Comparing the experimental value of Eg with the theoretical value obtained by the equation ⑥

9- The experiment is repeated for cooling

RESULT

The bandgap energies are calculated at different temperatures and Experimental values are compared with theoretical value

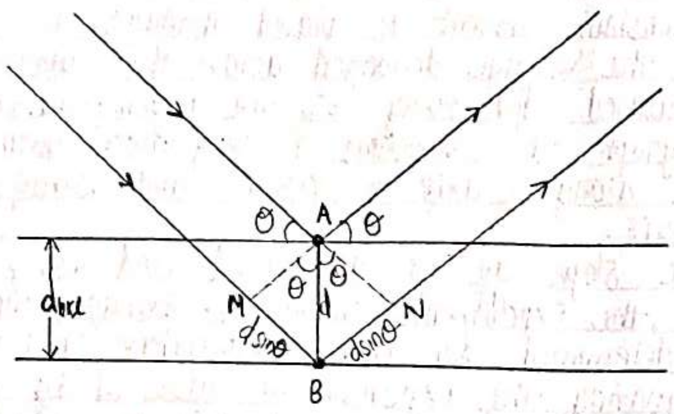
Mean theoretical value E_g = 1.115 eV

Mean Experimental value E_g = 1.230 eV

Error percentage = 10.3%

18/7/24

X-RAY DIFFRACTION

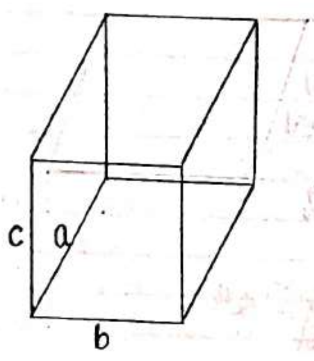


path difference = MB + BN

= d sinθ + d sinθ

= 2d sinθ

UNIT CELL



$\lambda = 1.5418\ \mathring{A} = 1.5418 \times 10^{-10}$ m

EXPERIMENT 8 DATE - 8/5/2024

XRD - CRYSTAL STRUCTURE DETERMINATION

AIM

Using X-ray diffraction data to calculate lattice parameter of some common material (Aluminium powder) with cubic structure.

REQUIRMENTS

XRD data of aluminium powder sample

THEORY

X-ray diffraction is a powerful technique used to study the structure of crystalline materials. When X rays interact with a crystalline sample, they are scattered by the atoms within the crystal lattice as shown in the figure. The scattering occurs due to the periodic arrangement of atoms, which act as scattering centers for the incident X-rays. This scattering phenomenon produces constructive interference in certain directions, resulting in diffraction peaks observed on a detector. These diffraction pattern that can be analyzed to determine the crystal structure and lattice parameters.

The fundamental principle governing X-ray diffraction is Bragg's law, which relates the wavelength of the incident X-rays, the angle of incidence, and

2θ degree	θ degree	$\sin\theta$	$\sin^2\theta$	$\frac{\sin^2\theta_n}{\sin^2\theta_1}$	$h^2+k^2+l^2$	hkl	$d_{hkl} = \frac{n\lambda}{2\sin\theta}$ (m)	$a = d_{hkl}\sqrt{h^2+k^2+l^2}$ $\times 10^{-10}$ (m)
38.497	19.2485	0.32966	0.10867	1	3	111	2.297×10^{-10}	4.0502
44.749	22.3745	0.38065	0.14489	1.33333	4	200	1.989×10^{-10}	3.979
65.115	32.5575	0.53814	0.28959	2.66485	8	220	1.407×10^{-10}	3.9808
78.239	39.1195	0.63093	0.39807	3.66310	11	311	1.200×10^{-10}	3.9814
82.447	41.2235	0.65899	0.43426	3.99613	12	222	1.1493×10^{-10}	3.9814

Mean lattice parameter $a = 3.9945\times10^{-10}$ m

Lattice parameter of Al powder $a = 4.0479\times10^{-10}$ m

the interplanar spacing of the crystal planes.

Bragg's Law is given by:

$$n\lambda = 2d\sin\theta \quad (1)$$

where,

n – Order of diffraction, usually $n=1$

λ – wavelength of the X-rays

d – interplanar spacing

θ – Angle of incidence/ Bragg angle.

When X-rays hit the crystal planes at an angle θ, constructive interference occurs if the path difference between the waves scattered from successive planes equals an integer multiple of the wavelength. This results in a diffraction peak at angle 2θ

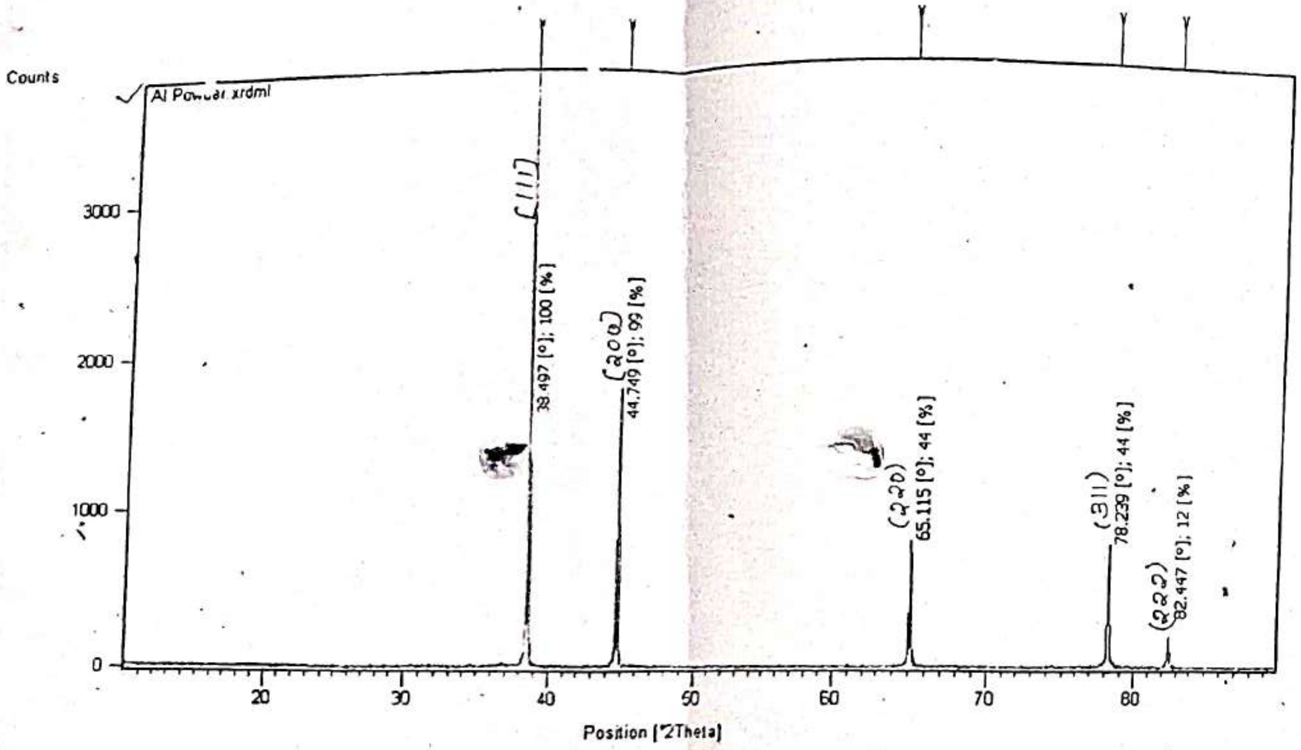
The planes in a crystal are described by Miller indices, denoted as (hkl). For a cubic crystal, the interplanar spacing d_{hkl} is related to the lattice parameter 'a' and the Miller indices by:

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}} \quad (2)$$

By measuring the diffraction angles 2θ and applying Bragg's law, the interplanar spacing (d) can be determined.

From (1) $d_{hkl} = \frac{n\lambda}{2\sin\theta}$ (3)

Dr. Manjusha M. V.



Copper Kα. $\lambda = 1.5418\,Å$

(1)

ameter:

$\ldots \sqrt{h^2+k^2+l^2}$. (4)

from (3), we get

$\ldots\lambda \sqrt{h^2+k^2+l^2}$. (5)
$\ldots\sin\theta$

and clear peak from the ... XRD ... value and find θ value. ... iller Indices and note down value

... distance d_{hkl}; using equation (3) parameter 'a' of sample using ... tion ((4) or (5))

Al powder with cubic structure

m

$\sin^2\theta_1$ ... 3

$$a = \frac{1.5148 \times 10^{-10}\sqrt{11}}{2 \times 0.63093} = \underline{3.9814 \times 10^{-10}\,m}$$

(5) $\frac{\sin^2\theta_5}{\sin^2\theta_1} = 3.99613 = \frac{12}{3}$, $h^2+k^2+l^2 = 12$, $a = \frac{1.5148 \times 10^{-10}\sqrt{12}}{2 \times 0.65899} = \underline{3.9814 \times 10^{-10}\,m}$

$$\frac{\sin^2\theta_1}{\sin^2\theta_1} = \frac{0.10867}{0.10867} = 1 = \frac{3}{3}$$

$h^2+k^2+l^2 = 3$ (111)

$$d_{hkl} = \frac{n\lambda}{2\sin\theta} = \frac{1.5418\times10^{-10}}{2\times0.32966} = 2.3384\times10^{-10}\ m$$

$$a = d_{hkl}\sqrt{h^2+k^2+l^2} = 2.3387\times10^{-10}\sqrt{3} = \underline{4.0502\times10^{-10}\ m}$$

$$\frac{\sin^2\theta_2}{\sin^2\theta_1} = 1.3333 = \frac{4}{3}$$

$h^2+k^2+l^2 = 4$ (200)

$$a = \frac{n\lambda\sqrt{h^2+k^2+l^2}}{2\sin\theta} = \frac{1.5148\times10^{-10}}{2\times0.38065}\sqrt{4} = \underline{3.979\times10^{-10}\ m}$$

$$\frac{\sin^2\theta_3}{\sin^2\theta_1} = 2.66485 = \frac{8}{3}$$

$h^2+k^2+l^2 = 8$ (220)

$$a = \frac{1.5148\times10^{-10}}{2\times0.53814}\sqrt{8} = \underline{3.9808\times10^{-10}\ m}$$

$$\frac{\sin^2\theta_4}{\sin^2\theta_1} = 3.66310 = \frac{11}{3}, \quad h^2+k^2+l^2 = 11$$

$$a = \frac{1.5148\times10^{-10}\sqrt{11}}{2\times0.63093} = \underline{3.9814\times10^{-10}\ m}$$

$$\frac{\sin^2\theta_5}{\sin^2\theta_1} = 3.99613 = \frac{12}{3}, \quad h^2+k^2+l^2=12, \quad a = \frac{1.5148\times10^{-10}\sqrt{12}}{2\times0.65899} = \underline{3.9814\times10^{-10}\ m}$$

From (2), lattice parameter:

$$a = d_{hkl}\sqrt{h^2+k^2+l^2} \qquad (4)$$

Substitute for d_{hkl} from (3), we get

$$a = \frac{n\lambda}{2\sin\theta}\sqrt{h^2+k^2+l^2} \qquad (5)$$

PROCEDURE

1 – Identify sharp and clear peak from the given pattern of XRD
2 – Note down 2θ value and find θ value.
3 – determine the Miller indices and note down value for each peak
4 – Find interplanar distance d_{hkl} using equation (3)
5 – Find the lattice parameter 'a' of sample using appropriate equation ((4) or (5))

RESULT

Lattice parameter of Al powder with cubic structure
$a = 3.9945\times10^{-10}\ m$

24/7/24

OBSERVATION AND CALCULATIONS

2θ degree	θ degree	$\sin\theta$	$\sin^2\theta$	$\frac{\sin^2\theta_n}{\sin^2\theta_1}$	$h^2+k^2+l^2$	[hkl]	$d_{hkl} = \frac{n\lambda}{2\sin\theta}$ $\times 10^{-10}$ m	$a = d_{hkl}\sqrt{h^2+k^2+l^2}$ $\times 10^{-10}$ m
28.362	14.181	0.2449	0.0599	1	3	111	3.0926	5.356
47.090	23.545	0.3994	0.1595	2.6627	8	220	1.8963	5.363
55.849	27.924	0.4682	0.2192	3.6594	11	311	1.6176	5.365
68.739	34.369	0.5645	0.3186	5.3188	16	400	1.3417	5.366
75.914	37.957	0.6150	0.3782	6.3138	19	331	1.2315	5.368
78.218	39.109	0.6308	0.3979	6.6427	20	420	1.2006	5.369

Mean lattice parameter $a = 5.3645 \times 10^{-10}$ m

The lattice parameter of CaF_2 unit cell, $a = 5.451$ Å $= 5.451 \times 10^{-10}$ m

EXPERIMENT 9 DATE – 9/5/2024

XRD-LATTICE PARAMETER MEASUREMENTS

AIM

To determine lattice parameter of a crystalline sample (CaF_2) using XRD data

REQUIRMENTS

XRD data of CaF_2 crystalline sample.

THEORY

X-ray diffraction is a powerful technique used to analyze the structure of crystalline materials. When X-rays are incident on a crystal, they are diffracted according to Bragg's law:

$$n\lambda = 2d\sin\theta \qquad (1)$$

where,

n – Order of diffraction, usually equal to one
λ – wavelength of the X-rays
d – interplanar spacing
θ – angle of incidence.

When X-rays hit the crystal planes at an angle θ, constructive interference occurs if the path difference the waves scattered from successive planes equals an integer multiple of the wavelength. This result in a

(1) $\frac{\sin^2\theta_1}{\sin^2\theta_1} = 1 = \frac{3}{3}$, $h^2+k^2+l^2=3$

$$d_{hkl} = \frac{n\lambda}{2\sin\theta} = \frac{1.5148\times10^{-10}}{2\times 0.2449} = \underline{3.0926\times10^{-10}\,m}$$

$$a = d_{hkl}\sqrt{h^2+k^2+l^2} = 3.0926\times10^{-10}\sqrt{3} = \underline{5.356\times10^{-10}\,m}$$

(2) $\frac{\sin^2\theta_2}{\sin^2\theta_1} = 2.6627 = \frac{8}{3}$, $h^2+k^2+l^2=8$

$$d_{hkl} = \frac{1.5148\times10^{-10}}{2\times 0.3994} = \underline{1.8963\times10^{-10}\,m}$$

$$a = 1.8963\times10^{-10}\sqrt{8} = \underline{5.363\times10^{-10}}$$

(3) $\frac{\sin^2\theta_3}{\sin^2\theta_1} = 3.6594 = \frac{11}{3}$, $h^2+k^2+l^2=11$

$$d_{hkl} = \frac{1.5148\times10^{-10}}{2\times 0.4682} = 1.6176\times10^{-10}\,m$$

$$a = 1.6176\times10^{-10}\times\sqrt{11} = \underline{5.365\times10^{-10}\,m}$$

(4) $\frac{\sin^2\theta_4}{\sin^2\theta_1} = 5.3188 = \frac{16}{3}$, $h^2+k^2+l^2=16$

$$d_{hkl} = \frac{1.5148\times10^{-10}}{2\times 0.5645} = \underline{1.3417\times10^{-10}\,m}$$

$$a = 1.3417\times10^{-10}\sqrt{16} = \underline{5.366\times10^{-10}\,m}$$

diffraction peak at angle 2θ

The planes in a crystal are described by Miller indices [hkl]

For a cubic crystal, the interplanar distance d_{hkl} is related to the lattice parameter 'a' and the Miller indices by

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}} \quad (2)$$

By measuring the diffraction angle 2θ and applying Bragg's law, the interplanar distance can be determined

ie, from (1)

$$d_{hkl} = \frac{n\lambda}{2\sin\theta} \quad (3)$$

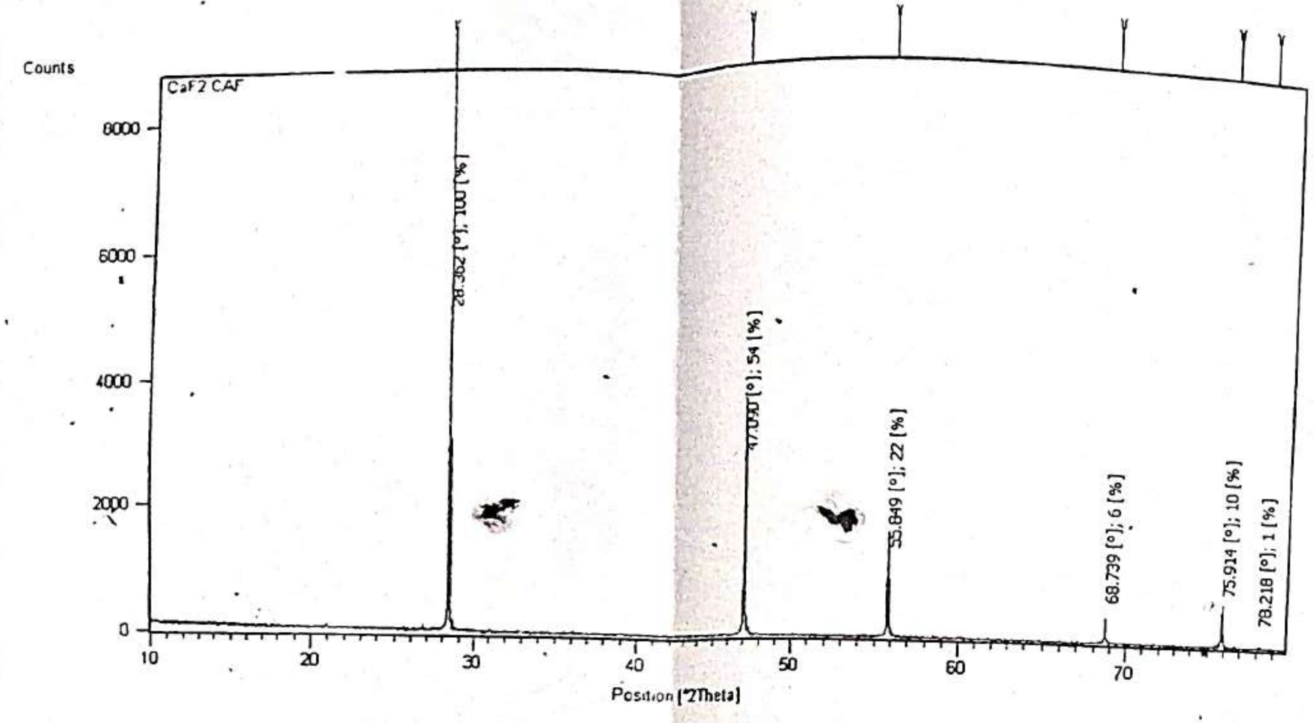
And from (2)

$$a = d_{hkl}\sqrt{h^2+k^2+l^2}$$

$$a = \frac{n\lambda}{\sin\theta}\sqrt{h^2+k^2+l^2}.$$

PROCEDURE

1 - Identify sharp and clear peak from the given pattern of XRD
2 - Note down 2θ value and find θ value.
3 - Determine the Miller indices and notedown value for each peak
4 - Find interplanar distance d_{hkl} using Bragg's law



parameter 'a' of given sample
e. equation.

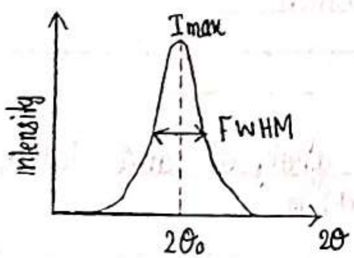
is analysed and lattice parameter
.3645 x10^{-10} m

5- Find the lattice parameter 'a' of given sample using appropriate equation.

RESULT

The XRD of CaF_2 is analysed and lattice parameter is found, $a = 5.3645 \times 10^{-10}$ m

2/7/24



EXPERIMENT 10 DATE- 10/5/24

XRD – DETERMINATION OF CRYSTALLITE SIZE AND LATTICE STRAIN

AIM

To determine the crystallite size and lattice strain of a given crystalline sample using X-ray diffraction data.

REQUIRMENTS

XRD of the sample

THEORY

In XRD data, the broadening β_D at peaks is due to the combined effect of crystallite size β_S and micro strain β_ε. ie,

$$\beta_D = \beta_S + \beta_\varepsilon \qquad (1)$$

Scherrer equation is used to calculate crystallite size and average crystallite size from XRD data.

From the Scherrer equation, we have,

$$\beta_S = \frac{K\lambda}{D\cos\theta} \qquad (2)$$

OBSERVATION AND CALCULATIONS

2θ degree	θ degree	θ radian	FWHM (β) degree	FWHM (β) radian	β cosθ	4 sinθ
22.295	11.1475	0.194561	0.274	0.004782	0.004692	0.773342
27.836	13.918	0.242915	0.215	0.003752	0.003642	0.962132
31.63	15.815	0.276024	0.568	0.009913	0.009538	1.090129
32.598	16.299	0.284471	0.212	0.0037	0.003551	1.1226
39.347	19.6735	0.343364	0.255	0.004451	0.004191	1.346639
46.069	23.0345	0.402028	0.243	0.004241	0.003903	1.565141

$$D = \frac{K\lambda}{\beta_S \cos\theta} \quad (3)$$

where,

β_S – Broadening due to crystallite size.
K – Shape factor or Scherrer constant, typically 0.9.
λ – wavelength of x-ray $= 1.5418 \times 10^{-10}$ m
D – Crystallite size
θ – Bragg angle in radian

Similarly, broadening due to microstrain is given by:

$$\beta_\varepsilon = 4\varepsilon \tan\theta \quad (4)$$

where,
ε is the strain

Combining equations (1), (2) and (4)

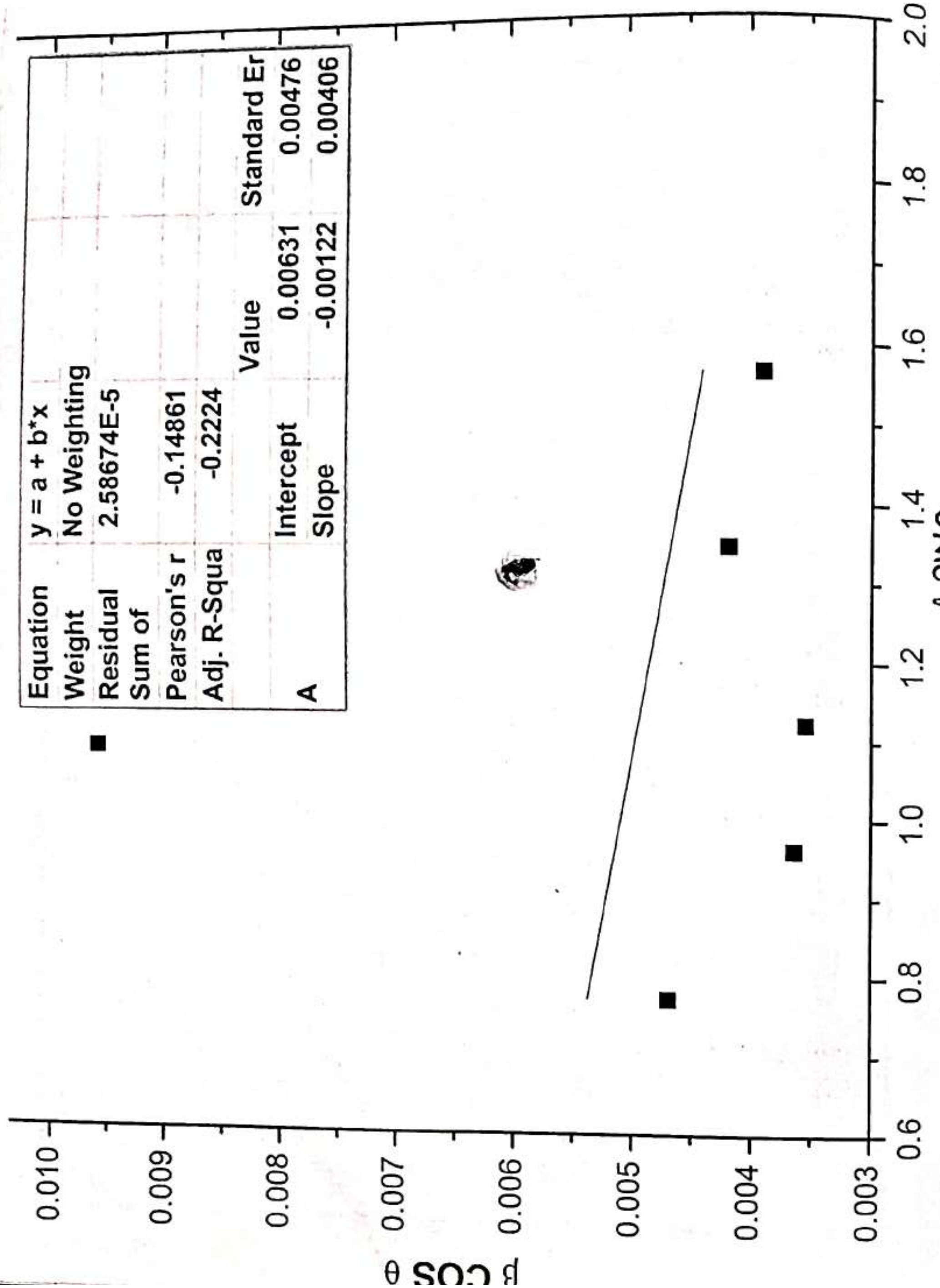
$$\beta_D = \frac{K\lambda}{D\cos\theta} + 4\varepsilon \tan\theta \quad (5)$$

$$\beta_D = \frac{K\lambda}{D\cos\theta} + 4\varepsilon \frac{\sin\theta}{\cos\theta}$$

Multiply throughout by $\cos\theta$.

$$\beta_D \cos\theta = \frac{K\lambda}{D} + 4\varepsilon \sin\theta \quad (6)$$

Equation (6) is similar to the equation of a straight line, $y = mx + c$ (7)



where,

m – slope of the straight line

c – y intercept

Comparing (6) and (7), we can write;

$$y = \beta_D \cos\theta \quad (8)$$

$$m = \varepsilon \quad (9)$$

$$c = \frac{k\lambda}{D} \quad (10)$$

WILLIAMSON-HALL PLOT

plot $\beta\cos\theta$ on the y axis against $4\sin\theta$ on the x axis. Fit a straight line to the data points. Such a plot is called Williamson-Hall plot. From the y intercept (c), we can calculate the Crystallite size (D) using equation (10). The slope (m) of the line gives the lattice strain (ε)

PROCEDURE

1 – Notedown 2θ values and FWHM values of the sample given.
2 – Convert 2θ to θ and degrees to radian.
3 – Convert FWHM (β) from degrees to radian.
4 – Calculate $\beta\cos\theta$ and $4\sin\theta$.
5 – Plot $\beta\cos\theta$ on the y axis against $4\sin\theta$ on the x axis and fit a straight line to the data points using software Originlab.
6 – Record the y-intercept (c) and calculate the Crystallite size (D) using equation (10)

From plot

Slope = ε = −0.00122.

Grain size $D = \frac{K\lambda}{c} = \frac{0.9 \times 1.514 \times 10^{-10}}{0.00631} = \underline{\underline{2.219 \times 10^{-8}\ m}}$

7 - Record the slope of the line, which gives the lattice strain (ε).

PLOTTING PROCEDURE IN ORIGINLAB

1 - Import your data from Excel file or text file into Origin lab.
2 - Ensure your data is in two colums: $4\sin\theta$ & $\beta\cos\theta$
3 - Highlight the columns of data by selecting.
4 - From the menu or options given in the lower portion of the lab select the scatter option for ploting.
5 - This will create a scatter plot with $4\sin\theta$ on the x axis and $\beta\cos\theta$ on the y axis
6 - With the scatter plot active go to Analysis menu and select fitting > Linear fit > open dialogue
7 - click ok to fit the data
8 - Originlab will add a fitted line to the scatter plot and display the fitting parameters, which include the slope (m) and y intercept (c)

RESULT

The XRD of given sample is analysed. The crystallite size and lattice strain obtained

If we have a positive slope, it means lattice is under tensile strain and a negative strain indicates compressive strain

Lattice strain ε = −0.0012.

Crystallite size $D = \underline{2.219 \times 10^{-8}}$ m.

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USING CONSTANTS AND CALCULATION, CONVERSION

$h = 6.626 \times 10^{-34}$ Js
$C = 3 \times 10^{8}$ m/s

$1J = 6.242 \times 10^{18}$ eV
$1m = 10^{9}$ nm

$h\nu = \frac{hc}{\lambda}$

$hc = 6.626 \times 10^{-34}$ Js $\times 3 \times 10^{8}$ m/s $= 1.986 \times 10^{-25}$ Jm

To convert Jm to eV.nm.

$hc = 1.986 \times 10^{-25} \text{ Jm} \times \frac{6.242 \times 10^{18} \text{ eV}}{1J} \times \frac{10^{9} \text{ nm}}{1m}$

$= \underline{\underline{1240 \text{ eV.nm}}}$

EXPERIMENT 11 DATE - 13/5/24

BAND GAP AND TYPE OF OPTICAL - TRANSITION (DIRECT OR INDIRECT USING TAUC RELATION) FROM ABSORPTION SPECTRA

AIM

To determine the band gap energy of a material using UV-visible absorption data with the Tauc plot method.

REQUIRMENTS

UV-visible absorption data of MgO

THEORY

UV-visible spectroscopy measures how much light a material absorbs. This can be done using either absorption or reflection spectroscopy. The intensity of light passing through or reflected by a sample is measured, usually in terms of transmittance or absorbance.

Materials absorb light at specific wavelengths corresponding to energy transitions within the material. For semiconductors, the band gap energy is a key value representing the energy difference between the valence band and the conduction band.

OBSERVATION AND CALCULATION

wavelength (nm) (λ)	Absorbance (A)	Absorption coeff $\alpha = 2.303\ A$	Energy $h\nu = \frac{1240}{\lambda}$	$(\alpha h\nu)^2$	$(\alpha h\nu)^{1/2}$

In direct band gap semiconductors, the top of the valence band and the bottom of the conduction band occur at the same momentum value, allowing electrons to directly transition between these bands by absorbing or emitting a photon. For indirect bandgaps, the transition involves a change in momentum, typically requiring a phonon in addition to the photon.

The optical band gap of a material can be determined using it's absorption spectrum. The absorption coefficient α near the absorption edge is related to the photon energy $h\nu$ by the Tauc relation, which varies depending on whether the optical transition is direct or indirect.

For direct transitions:

$$(\alpha h\nu)^2 = A(h\nu - E_g)$$

For indirect transitions:

$$(\alpha h\nu)^{1/2} = A(h\nu - E_g)$$

Where,

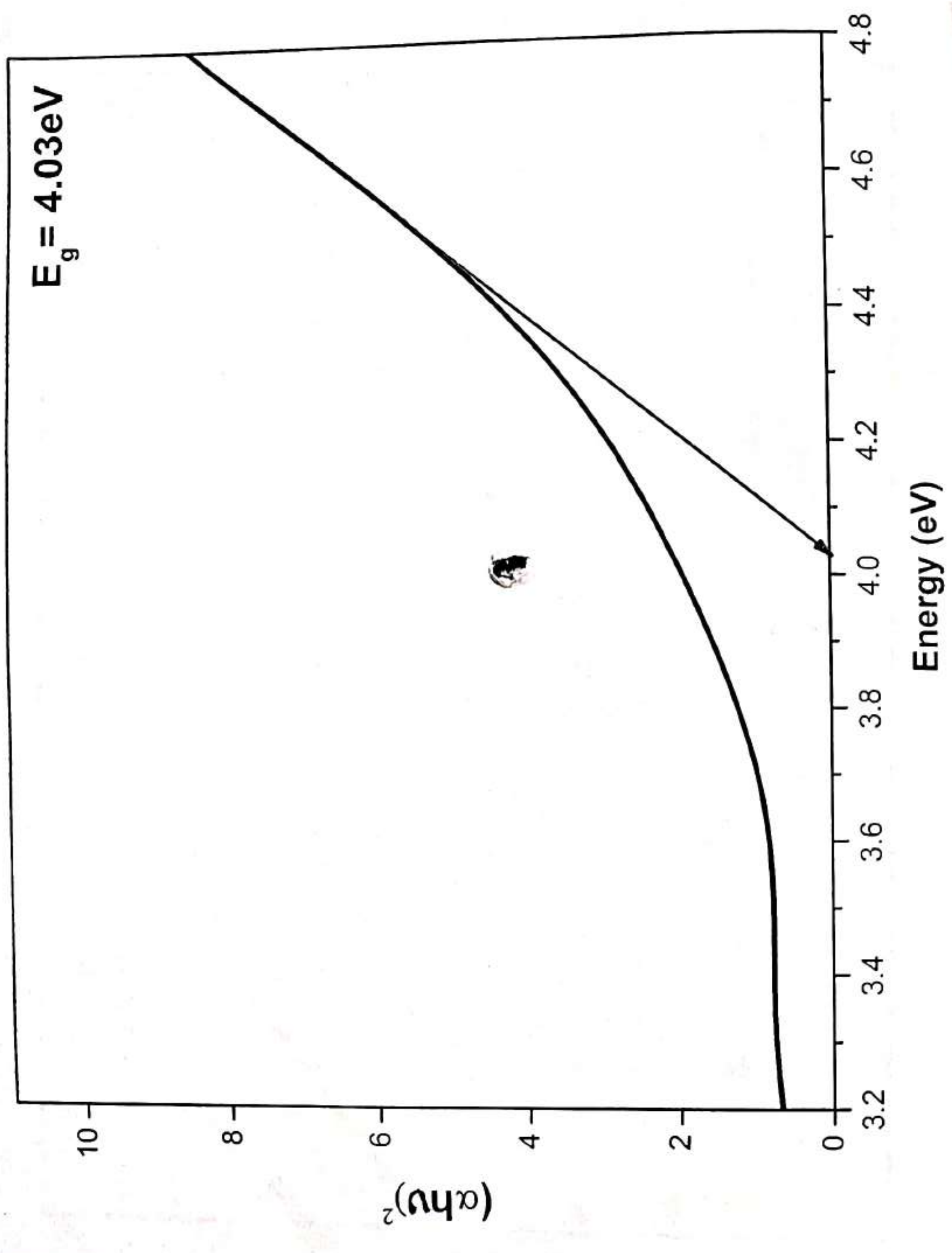
α – absorption coefficient, $\alpha = \frac{2.303 \times \text{absorbance}}{t}$

$h\nu$ – photon energy

E_g – Bandgap energy t = thickness of the material

A – A constant

By plotting $(\alpha h\nu)^2$ vs $h\nu$ for direct transitions or $(\alpha h\nu)^{1/2}$ vs $h\nu$ for indirect transitions, the band gap can be determined from the intercept of



linear portion of the plot with the $h\nu$ energy axis.

PROCEDURE

1 - Record the absorbance (A) and corresponding wavelength (λ)

2 - Convert the absorbance (A) to absorption coefficient α using the formula:

$$\alpha = \frac{A \times 2.303}{t}, \quad t = 1\,cm$$

3 - Convert the wavelength λ to photon energy $h\nu$ using the formula:

$$h\nu = \frac{hc}{\lambda} = \frac{1240\ (eV.nm)}{\lambda\ (nm)}$$

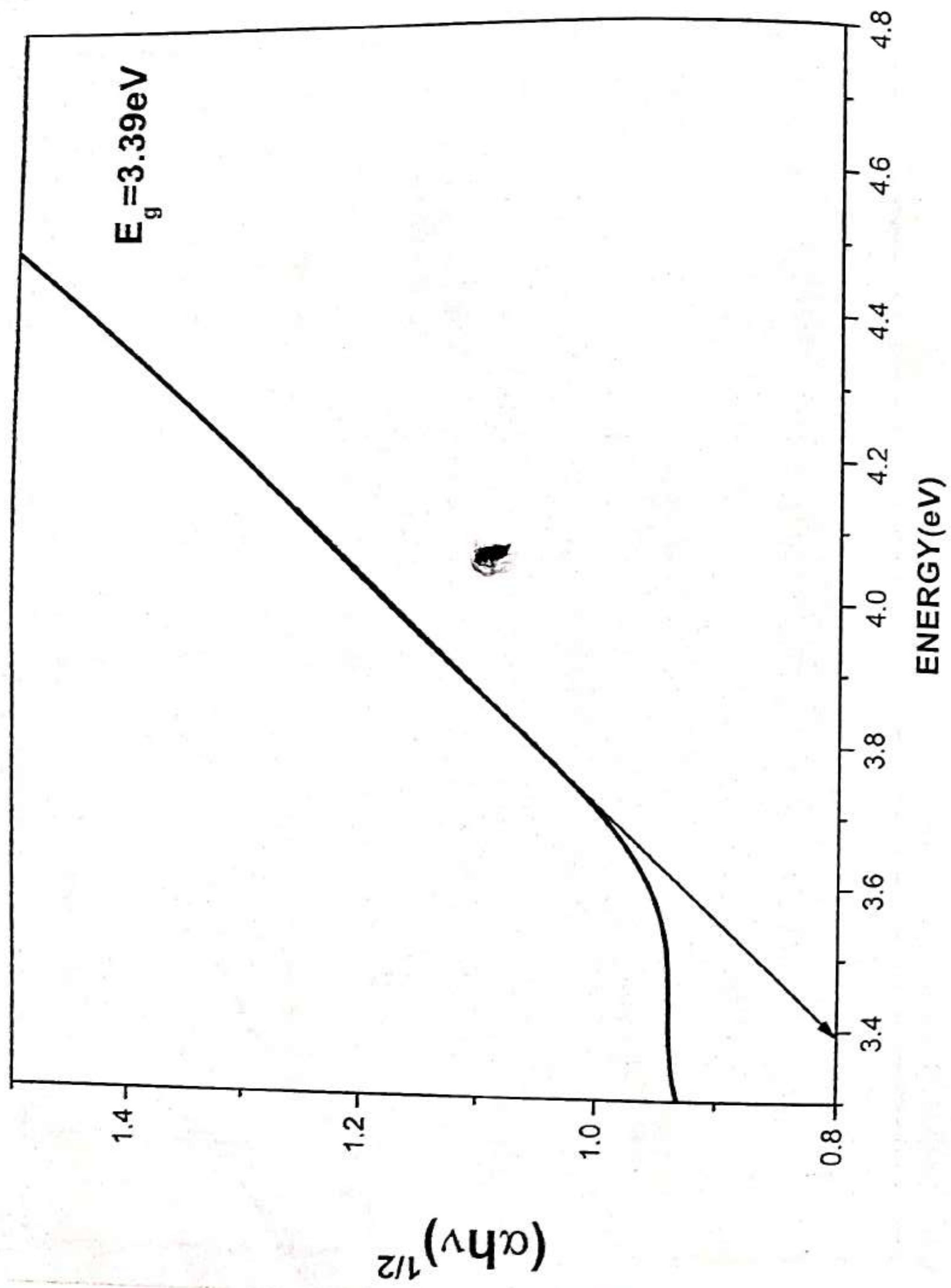
where, h - planck's constant
c - speed of light.

4 - plot $(\alpha h\nu)^{1/2}$ versus $h\nu$ to check for a linear relationship indicating an indirect transition

5 - plot $(\alpha h\nu)^2$ versus $h\nu$ to check for a linear relationship indicating a direct transition

6 - Fit a straight line to the linear portion of the plot on both plots using Originlab

7 - The intercept on the $h\nu$ axis gives the band gap energy Eg.



RESULT

Direct band gap energy of MgO, E_g = 4.18 eV
Experimental value, E_g = 4.03 eV

Indirect band gap energy of MgO, E_g = 3.40 eV
Experimental value, E_g = 3.39 eV

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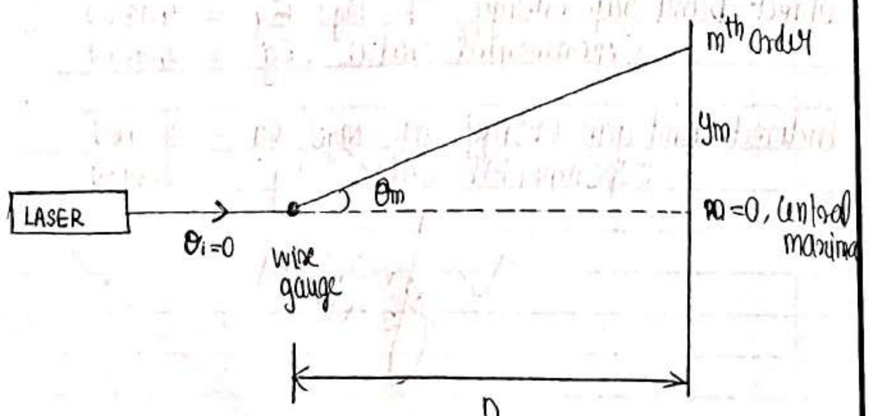


EXPERIMENT 12 DATE - 14/5/24

LASER DIFFRACTION - COMPARISON OF THICKNESS OF WIRES OF DIFFERENT GAUGES

AIM

To determine the diffraction pattern and to calculate the diameter 'd' of different gauges.

APPARATUS REQUIRED

Laser, meter scale, different wire gauges, graph paper etc.

THEORY

Diffraction is the phenomenon of bending of light around an obstacle or spreading of light around an obstacle caused by passing through an aperture, where the size of the obstacle or aperture is comparable to the wavelength of light.

Let a monochromatic laser light of wavelength λ is incident normally on an obstacle. As a result it creates a diffraction pattern of bright and dark fringes on a screen which kept at distance D from the wire gauge, the obstacle.

Let θ_m be the angle subtended between the central maximum and the m^{th} order maximum and

OBSERVATIONS AND CALCULATIONS

$\lambda = 535 \times 10^{-9}$ m

WIRE	Distance D (m)	Order m	Distance from central maximum: left	Right	Mean $\times10^{-3}$ (mm)	$\theta = \tan^{-1}\frac{Y_m}{D}$	$\sin\theta$ $\times10^{-3}$	$d = \frac{m\lambda}{\sin\theta}$ $\times10^{-3}$
I	1.78	1	3	3	3	0.0965	1.6842	0.3176
		2	4.5	4.5	4.5	0.1448	2.5272	0.4233
		3	6	6	6	0.1931	3.3702	0.4762
	1.84	1	3.2	3.2	3.2	0.0996	1.7383	0.3077
		2	4.5	4.5	4.5	0.1401	2.4452	0.4375
		3	7	7	7	0.2179	3.8030	0.4220
II	3.64	1	6	6	6	0.0944	1.6475	0.3247
		2	11	11	11	0.1731	3.0211	0.3541
		3	16	16	16	0.2518	4.3947	0.3652
	2.73	1	5	5.5	5.25	0.1101	1.9216	0.2784
		2	10	9.5	9.75	0.2046	3.5709	0.2996
		3	12	13	12.5	0.2623	4.5779	0.3505
III	2.6	1	2	2	2	0.0440	0.7679	0.6967
		2	5	6	5.5	0.1212	2.1153	0.5058
		3	8	8	8	0.1762	3.0752	0.5219
	2.42	1	3	3	3	0.0710	1.2391	0.4317
		2	5	5	5	0.1183	2.0647	0.5182
		3	7	7	7	0.1657	2.8920	0.5549

Mean diameter of wire I = 0.3973×10^{-3} m

Mean diameter of wire II = 0.3287×10^{-3} m

Mean diameter of wire III = 0.5382×10^{-3} m

Y_m be the distance on the screen from the mth order maximum to the central maximum.

The equation for diffraction is given by:

$$d(\sin\theta_i + \sin\theta_m) = m\lambda \quad (1)$$

where,

d – diameter of the wire.

θ_i – Angle of incidence.

Since the laser beam is incident normally on the wire, $\theta_i = 0$ equation (1) can be reduced to:

$$d\sin\theta_m = m\lambda$$

and

$$d = \frac{m\lambda}{\sin\theta_m} \quad (2)$$

The angle θ_m can be obtained from Y_m and D. From the figure, we can write

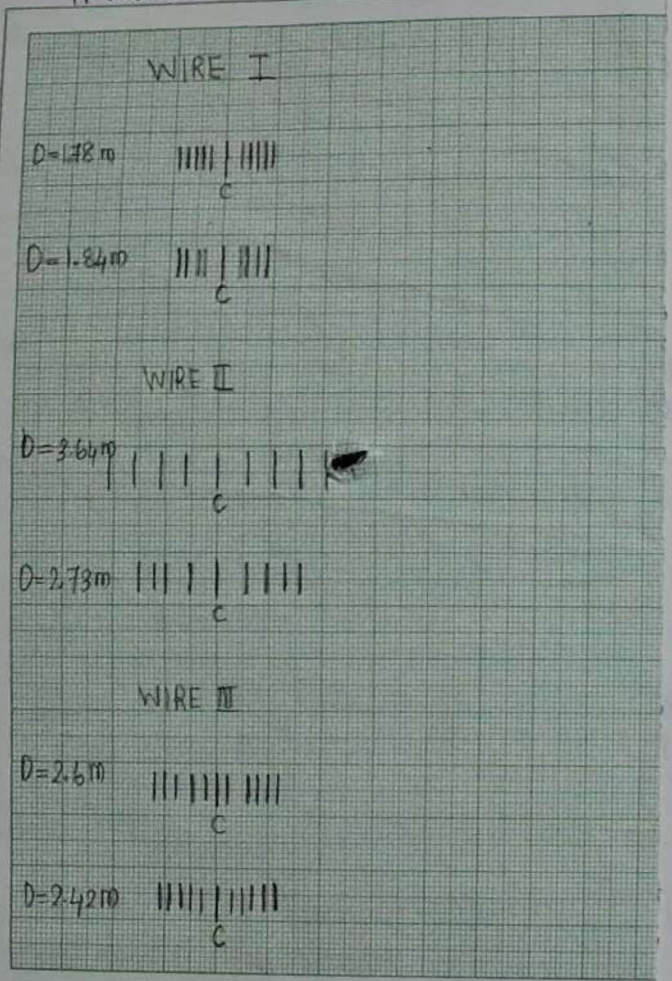
$$\tan\theta_m = \frac{Y_m}{D}$$

$$\theta_m = \tan^{-1}\frac{Y_m}{D} \quad (3)$$

PROCEDURE

1 – The laser source is switched on and light is allowed to fall normally on the wire gauge.

$\lambda = 535 \times 10^{-9}$ m



2 – Sketch the diffraction pattern obtained on a screen in a graph paper

3 – Measure the distance (D) from the wire gauge to the screen.

4 – Determine the distance y_m for different orders of maxima from the central maximum.

5 – Thus, the diameter 'd' is calculated using the formula

$$d = \frac{m\lambda}{\sin\theta_m}$$

where, $\theta_m = \tan^{-1}\frac{y_m}{D}$

RESULT

The diameter or thickness of different gauge wires are calculated.

diameter of wire I = 0.3978×10^{-3} m

diameter of wire II = 0.3287×10^{-3} m

diameter of wire III = 0.5382×10^{-3} m.

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Completed