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SINHGAD COLLEGE OF ENGINEERING

[Affiliated to Savitribai Phule Pune University & Approved by AICTE (ID No.PU/PN/Engg/116(1996)]
S.No. 44/1, Vadgaon (Bk.), Off Sinhgad Road, Pune-411041.

Laboratory Manual

- The department prepares and share the Laboratory manual as per syllabus and guidelines from Board of Study. This manual guide the students to complete the assignment. The sample laboratory manual is shared for the academic year 2022-23.

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Sr. No.	Description
1	FE Department
2	Electronics & Telecommunication
3	Computer Engineering

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S.No. 44/1, Vadgaon (Bk), off Sinhgad Road, Pune – 411 041.

Accredited by NAAC with 'A+' Grade

Department of Engineering Sciences

Certificate

Mr. /~~Ms~~. ...Raut Sameer siddheshwar............
of First Year Division ...2C...... Roll No. ...102051.........
has completed all the practical work in the subject **Engineering Physics** satisfactorily in the department of Engineering Sciences as prescribed by Savitribai Phule Pune University, in the academic year 20.22-20.23

30/1

Faculty-in-charge **Head of Department** **Principal**

Date: 30/01 /20.23..

Sinhgad Technical Education Society's

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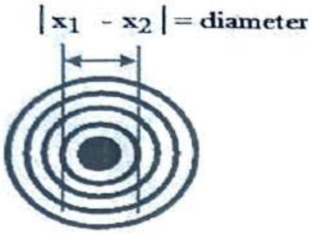
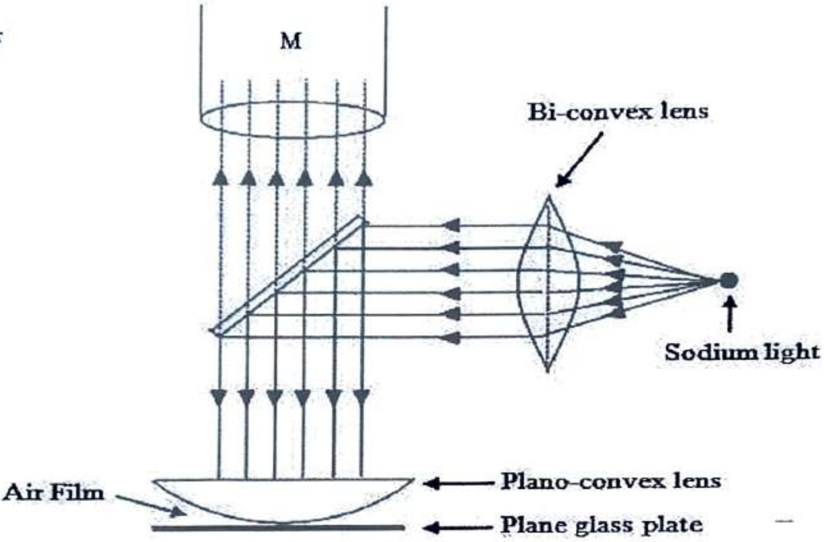
Expt. No. 1 | Newton's Ring

Aim: *To determine the radius of curvature of a Plano-convex lens using Newton's rings.*

Apparatus: *A traveling microscope, Newton's rings apparatus, Sodium lamp, Magnifying glass etc.*

Ray Diagram:





$$Least\ Count = \frac{Value\ of\ smallest\ division\ on\ M.S.}{Total\ number\ of\ divisions\ on\ V.S.}$$

$$Total\ Reading = M.S.R. + (V.S.R.\ \times\ L.C.)$$

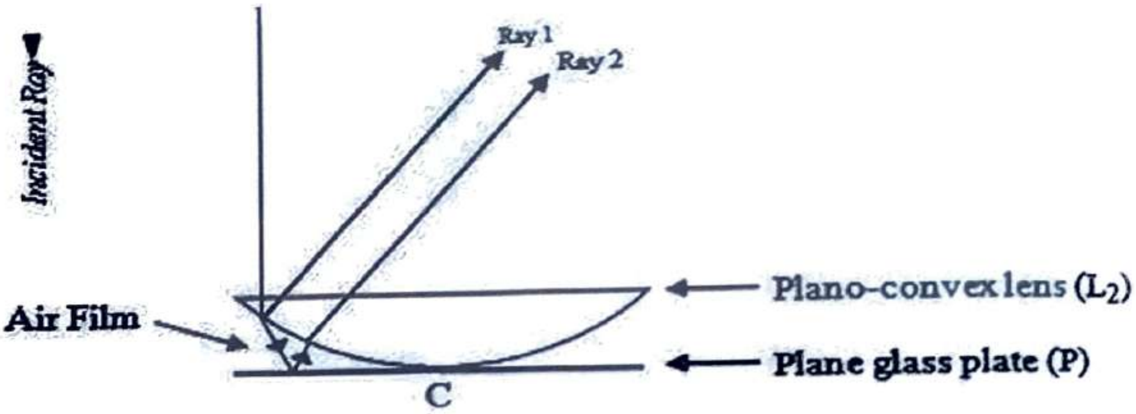
Theory:

When plano convex lens is placed on a plane glass-plate, a thin wedge shaped film of air is formed between the curved surface of convex lens and the plane surface of glass plate of progressively increasing thickness in all directions around the point of contact of lens and glass-plate.

Each ray of the normally incident beam from a monochromatic source falling on the lens -plate system gets reflected back from the top and bottom surfaces of the air film between the lens and plate. The two reflected rays are coherent. Therefore they produce interference. The locus of all points corresponds to equal thickness of air film fall on a circle whose center is 'c'. The interference fringes obtained are a series of concentric rings, alternately bright and dark with their center c. These rings are called Newton's rings. They are fringes of equal thickness. These rings are observed only within small area around the point of contact as the air film is very thin there.

The reflected rays are obtained through division of amplitude of the incident ray. Therefore this kind of interference occurring in the thin film of air belongs to the class of 'interference through division of amplitude'.

Theoretical diagram:



Theory of Newton's Rings:

In case of normal incidence the effective path difference. between the reflected rays is,

$$\Delta = 2\mu t + \frac{\lambda}{2}$$

For air, $\mu=1$,

$$\Delta = 2t + \frac{\lambda}{2}$$

Case I: At the point of contact C, $t = 0$

$$\Delta = \frac{\lambda}{2}$$

This is the condition of minimum intensity. Hence central spot is dark.

Case II: At the points other than C,

The film will appear bright if,

$$2t + \frac{\lambda}{2} = n\lambda \qquad \text{Where, } n = 0,1,2,3\ldots\ldots\ etc.$$

or

$$2t = (2n-1)\frac{\lambda}{2} \ \textit{Where}, \ n = 1,2,3\ldots\ldots\text{etc.}$$

The film will appear dark if,

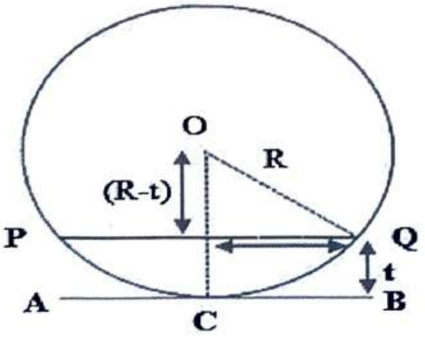
$$2t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2} \qquad \text{Where, } n = 1,2,3\ldots\ldots\ etc.$$

or

$$2t = n\lambda \qquad \text{Where, } n = 0,1,2,3\ldots\ldots\ etc.$$

Diameter of Newton's Rings:

Let PCQ be a plano-convex lens placed on a plane glass plate AB.



Let R be the radius of curvature of the lens surface which is in contact with the plate AB. Let r be the radius of Newton's ring corresponding to thickness t.

The path difference between the two interfering rays in the reflected system for normal incidence is,

$$\Delta = 2t + \frac{\lambda}{2}$$

From Figure,

$R^2 = r^2 + (R - t)^2$

i.e. $r^2 = R^2 - (R - t)^2$

i.e. $r^2 = R^2 - R^2 + 2Rt - t^2$

i.e. $r^2 = 2Rt - t^2$

But, t<<R hence we get,

$r^2 = 2Rt$

$2t = \frac{r^2}{R} = \frac{D^2}{4R}$ *Where, D is the diameter of Newton's Ring*

But we have for Newton's rings ,

$\Delta = 2t + \frac{\lambda}{2}$ i.e. $\Delta = \frac{r^2}{R} + \frac{\lambda}{2}$

For Dark Rings:

Condition to get dark ring is that the path difference,

$\frac{r^2}{R} + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$ i.e.

$\frac{r^2}{R} = n\lambda$ *Where, n=0,1,2,3............. etc.*

If 'D_n' is the diameter of nth dark Newton's ring then,

$\frac{D_n^2}{4} R = n\lambda$, or $D_n^2 = 4nR\lambda$

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

Similarly diameter of $(n + p)^{th}$ dark ring is,

$D_{n+p}^2 = 4(n+p)R\lambda$

$\therefore D_{n+p}^2 - D_n^2 = 4pR\lambda$

$$\therefore \lambda = \frac{D_{n+p}^2 - D_n^2}{4pR} \quad \text{or} \quad R = \frac{D_{n+p}^2 - D_n^2}{4p\lambda}$$

Thus by measuring the diameters of dark rings and radius of curvature R the wavelength l can be calculated or by knowing the wavelength l the value of radius of curvature R of a plano-convex lens can be calculated.

Procedure:

1. Arrange the apparatus as shown in the figure. Clean the lens and the glass plate thoroughly and put the plano-convex lens on the glass plate with its convex surface touching the glass plate. Put this lens-plate arrangement under the microscope.
2. Allow the parallel light from the sodium source to be incident on a glass plate which is held over the lens-plate arrangement at an angle of 45° with the direction of light. The reflected light from the glass plate falls on the lens-plate arrangement.
3. Adjust the microscope such that the point of contact between the lens and plate is just below the microscope. The Newton's rings are seen through the microscope because the air film is formed between the lens and the plate all around the point of contact.
4. Newton's rings consist of central dark spot surrounded by alternate bright and dark concentric rings.
5. The least count of the microscope is determined and recorded.
6. First the microscope is adjusted so that the center of cross wires coincides with the center of dark spot.
7. The microscope is then moved either to the left or right of the centre. While moving count the number of rings passing the field of view of microscope.
8. As the tenth ring approaches the vertical crosswire is adjusted such that it will be tangential to that ring. In this position reading of microscope is noted.
9. Reversing the motion of microscope, the vertical cross-wire is adjusted so that it will be tangential to next ring(9^{th}), reading of microscope is noted.
10. Above process is continued till first ring is reached. Reading of each ring is noted down.

11. Now the microscope is further moved in same direction till first ring on the other side approaches. The vertical cross-wire is again adjusted so that it will be tangential to first reading. Reading is noted down.
12. Move the microscope in the same direction and repeat the same procedure and note the readings for each ring till readings of 10th is noted.
13. Difference between left and right-hand readings for a particular dark ring .gives the diameter of that ring.
14. A graph is plotted for D_n^2 against n, where D_n^2 is a square of the diameter of a ring and n is the number of a ring. It is a straight line.
15. The slope of the graph is calculated.

Observations:

1. Least Count of traveling microscope = ...0.001........ cm.
2. Wavelength of Sodium lamp = λ = 5893 Å = ...5893×10^{-8}... cm.

Observation table:

Sr. No.	Number of Dark Ring (n)	Microscope reading		Diameter	D_n^2 in cm^2
		Left (x_1) cm.	Right (x_2) cm.	$D_n = \lvert x_1 - x_2 \rvert$ cm.	
1.	6	4.506	4.207	0.299	0.0894
2.	5	4.498	4.215	0.283	0.0800
3.	4	4.492	4.230	0.262	0.0686
4.	3	4.468	4.248	0.22	0.07
5.	2	4.446	4.269	0.177	0.03
6.	1	4.420	4.293	0.127	0.0161
7.					

Calculations:

$$Slope = \frac{D^2_{n+p} - D^2_n}{(n+p)-n} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.08-0.04}{5.3} = \frac{0.04}{2}\ cm^2 = 0.02 cm^2$$

$$R = \frac{Slope\ of\ graph\,(D^2_n \text{ Vs } n)}{4\lambda}$$

$$= \frac{0.02}{4 \times 5893 \times 10^{-8}}$$

$= 84.8464$ cm

Result: Radius of curvature of a given Plano-convex lens is 84.8464 cm

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	Ash 23/12
6	4	8	18	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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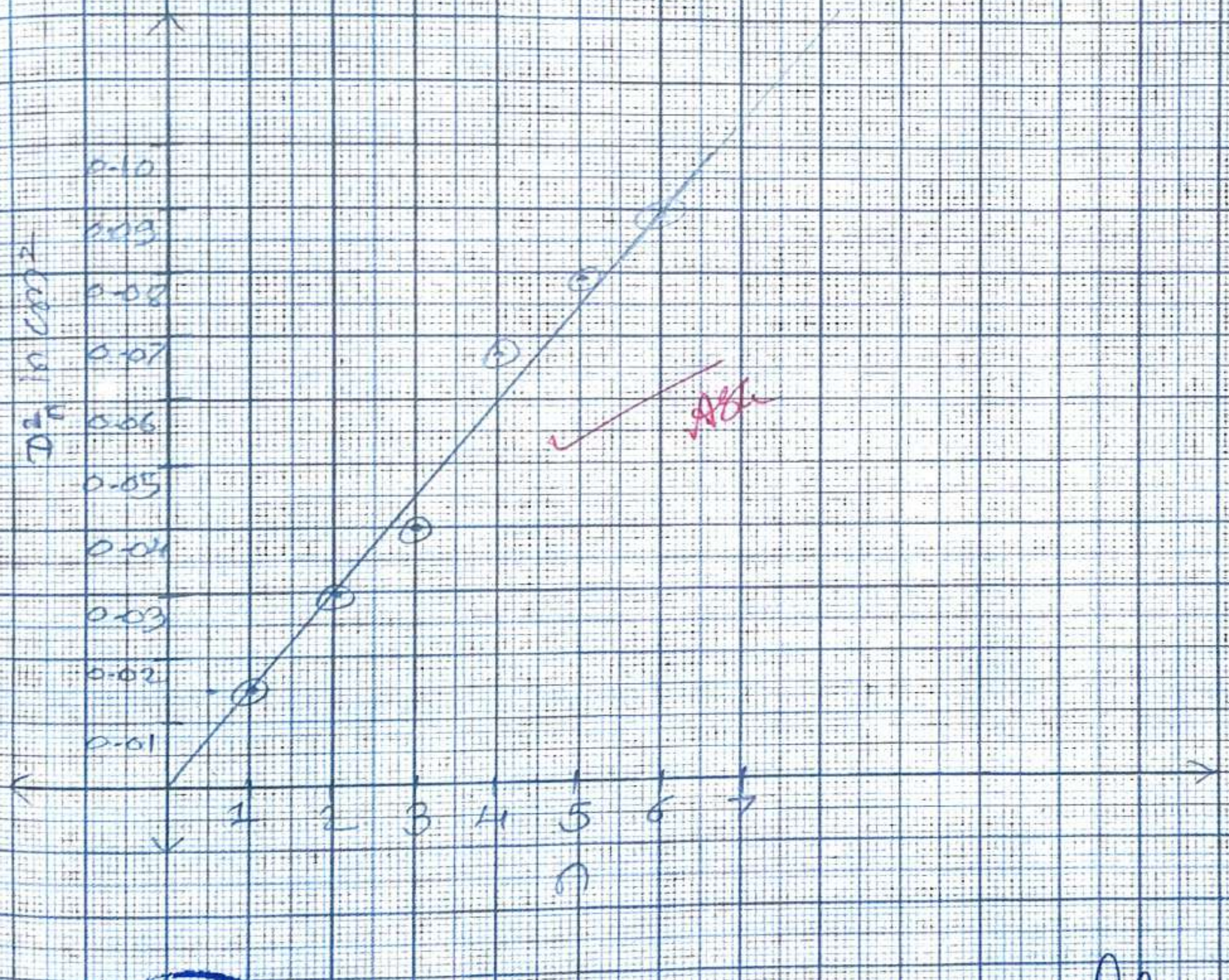
Scale

on x-axis: 1 cm = [illegible]

on y-axis: 1 cm = 1



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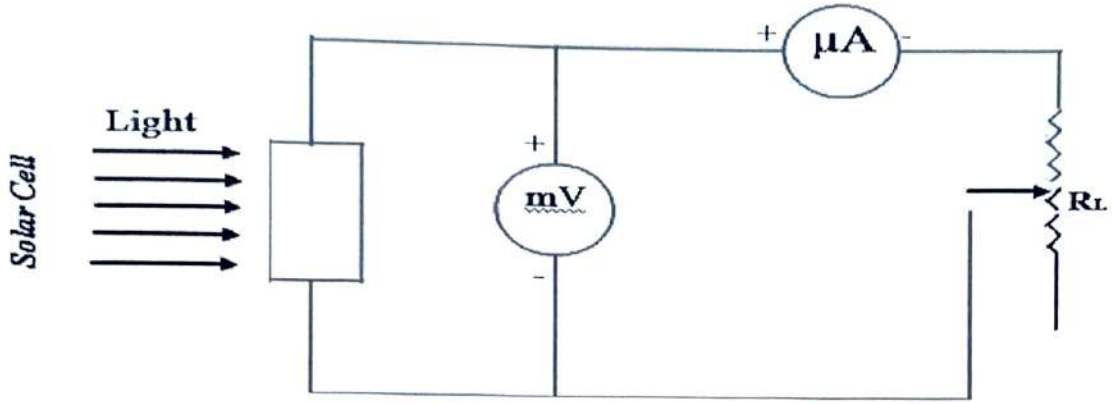
Expt. No. 2 | Solar cell

Aim: *To study the I-V characteristics of the given solar cell to calculate the fill factor and value of resistance for maximum value of workable power.*

Apparatus: *Solar cell, light source, variable load, voltmeter, ammeter, etc.*

Circuit Diagram:



Theory:

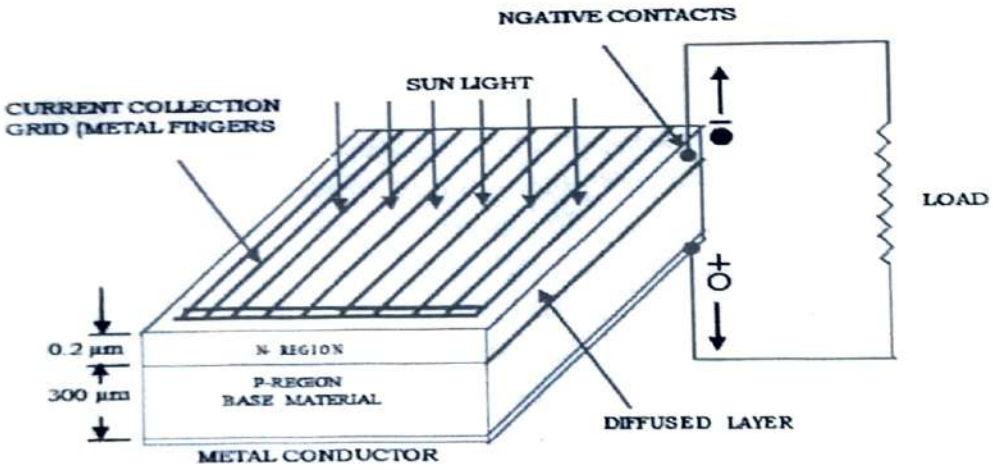
The direct conversion of solar energy by means of the photovoltaic effect, that is, the conversion of light (or other electromagnetic radiation) into electricity. The photovoltaic effect is defined as the generation of an electromotive force as a result of the absorption of ionizing radiation (later explained in detail). Energy conversion devices which are used to convert sunlight to electricity based on the photovoltaic effect are called solar cells. A single converter cell is called a solar cell or, more generally, a photovoltaic cell, and combination of such cells; designed to increase the electric power output is called solar module or solar array.

The photovoltaic effect can be observed in nature in a variety of materials, but the materials that have shown the best performance in sunlight are the semiconductors. When photons from the sun are absorbed in a semiconductor, they create free electrons with higher energies than the electrons which provide the bonding in the base crystal. Once these electrons are created, there must be an electric field to induce these higher energy electrons to flow out of the semiconductor to do useful work. The electric field in most solar cells is provided by a junction of materials which have different electrical properties.

To obtain a useful power output from photon interaction in a semi-conductor three processes are required.

1. The photons have to be absorbed in the active part of the material and result in electrons being excited to a higher energy potential.
2. The electron hole charge carriers created by the absorption must be physically separated and moved to the edge of the cell.
3. The charge carriers must be removed from the cell and delivered to a useful load before they loose their extra potential. For completing the above processes, a solar cell consists of:
    - (a) Semi-conductor in which electron hole pairs are created by absorption of incident solar radiation.
    - (b) Region containing a drift field for charge separation, and
    - (c) Charge collecting front and back electrodes.

The photo-voltaic effect can be described easily for p-n junction in semi-conductor.



In this junction after the photons are absorbed, the free electrons of the n-side will tend to flow to the p-side, and the holes of p-side will tend to flow to the n-region to compensate for their respective deficiencies. This diffusion will create an electric field E_F from the n-region to the p-region. This field will increase until it reaches equilibrium for Ve, the sum of the diffusion potentials for holes and electrons.

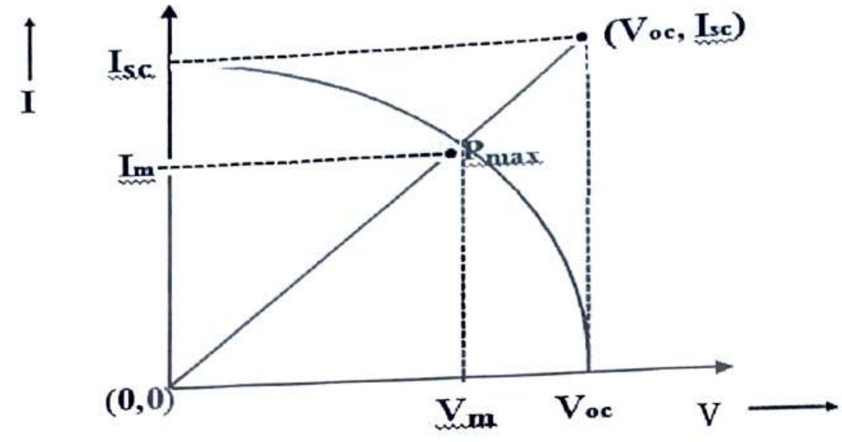
If electrical contacts are made with the two semiconductor materials and the contacts are connected through an external electrical conductor, the free electron will flow from the n-type material through the conductor to the p-type material as shown in the figure. Here the free electrons will enter the holes and become bound electrons; thus both free electrons and holes will be removed. The flow of electrons through the external conductor constitutes an electric current which will continue as long as more free electrons and holes are being formed by the solar radiation. This is the basis of photovoltaic conversion, that is, the conversion of solar energy into electrical energy. The combination of n-type and p-type semiconductors thus constitutes a photovoltaic (PV) cell or solar cell. All such cells generate direct current which can be converted into alternating current if desired.

Procedure:

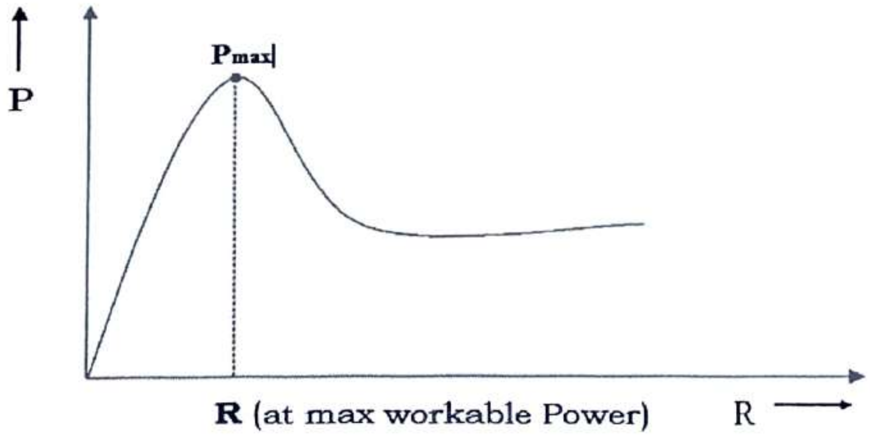
1. Connect the circuit, as shown in the circuit diagram and get it checked.
2. Start increasing the load (RL) and at selected voltage steps measure current. Take maximum possible readings for graph. Take the readings up to maximum load and record in the observation table.
3. Calculate the values of power and resistance
4. Plot the graph of. I Vs V. Draw a smooth curve from the points plotted. Extend the curve upto x and y axes as per the nature of the curve. We get the points Isc and Voc.
5. Draw perpendicular from Isc and Voc, we get a point (Isc,Voc). Draw a line joining origin (0,0) and the point (Isc,Voc). This line cuts the graph at point (Im,Vm). Draw perpendiculars from point (Im,Vm) on x and y axes. WE get the points Im and Vm.
6. Record Im, Vm, Isc, and Voc from the graph in the observations.
7. Plot the graph of P Vs R and record the value of resistance for maximum workable power.

Graphs:

1. Graph of I Vs V



2. Graph of Power (P) Vs load resistance (R)



Observation Table:

Obs. No.	Voltage in V	Current in mA	Current in A	Power (P)= VI in Watt	*Resistance* $(R)=\frac{V}{I}$ $Ohm(\Omega)$
1.	0.2	250	0.25	0.05	0.8
2.	0.25	250	0.25	0.06	1
3.	0.30	250	0.25	0.08	1.2
4.	0.35	245	0.245	0.09	1.4
5.	0.4	235	0.235	0.094	1.7
6.	0.45	230	0.23	0.10	2
7.	0.50	220	0.22	0.11	2.3
8.	0.55	210	0.21	0.12	2.6
9.	0.60	200	0.2	0.12	3
10.	0.65	190	0.19	0.12	3.4
11.	0.70	175	0.175	0.12	4
12.	0.75	170	0.17	0.13	4.4
13.	0.80	160	0.16	0.13	5
14.	0.85	150	0.15	0.13	5.7
15.	0.90	135	0.135	0.12	6.7
16.	0.95	130	0.13	0.12	7.3
17.	1	120	0.12	0.12	8.3
18.	1.05	110	0.11	0.11	9.5
19.	1.10	105	0.105	0.11	10.5
20.	1.15	95	0.095	0.10	12.1
21.	1.55	30	0.03	0.04	51

Observations from graph:

1. Open circuit voltage (V_{oc}) = 1.55 V.
2. Short circuit current (I_{sc}) = 250 mA.
3. Voltage corresponding to maximum power (V_m) = 1.025 V.
4. Current corresponding to maximum power (I_m) = 170 mA.

Calculations:

Fill Factor. $$FF = \frac{I_m \times V_m}{I_{sc} \times V_{oc}} = \frac{1.025 \times 170}{1.55 \times 250}$$

$$\therefore \quad FF = 0.449$$

Results:

1. Fill factor of the solar cell = 0.449
2. Resistance at maximum workable power (from graph) = 4.5 Ω.

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	15/12
6	6	8	20	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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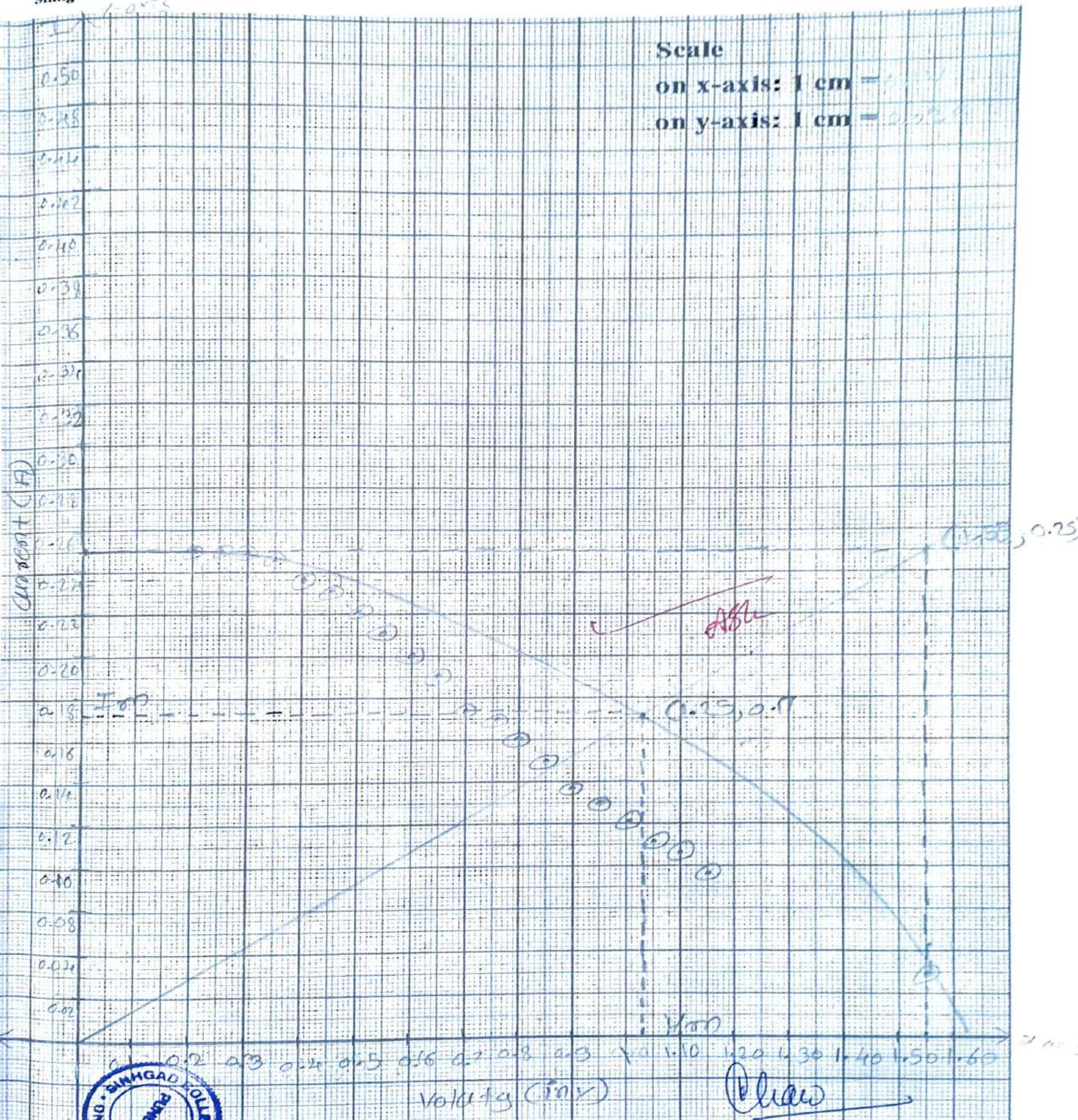

Scale
on x-axis: 1 cm = [illegible]
on y-axis: 1 cm = [illegible]

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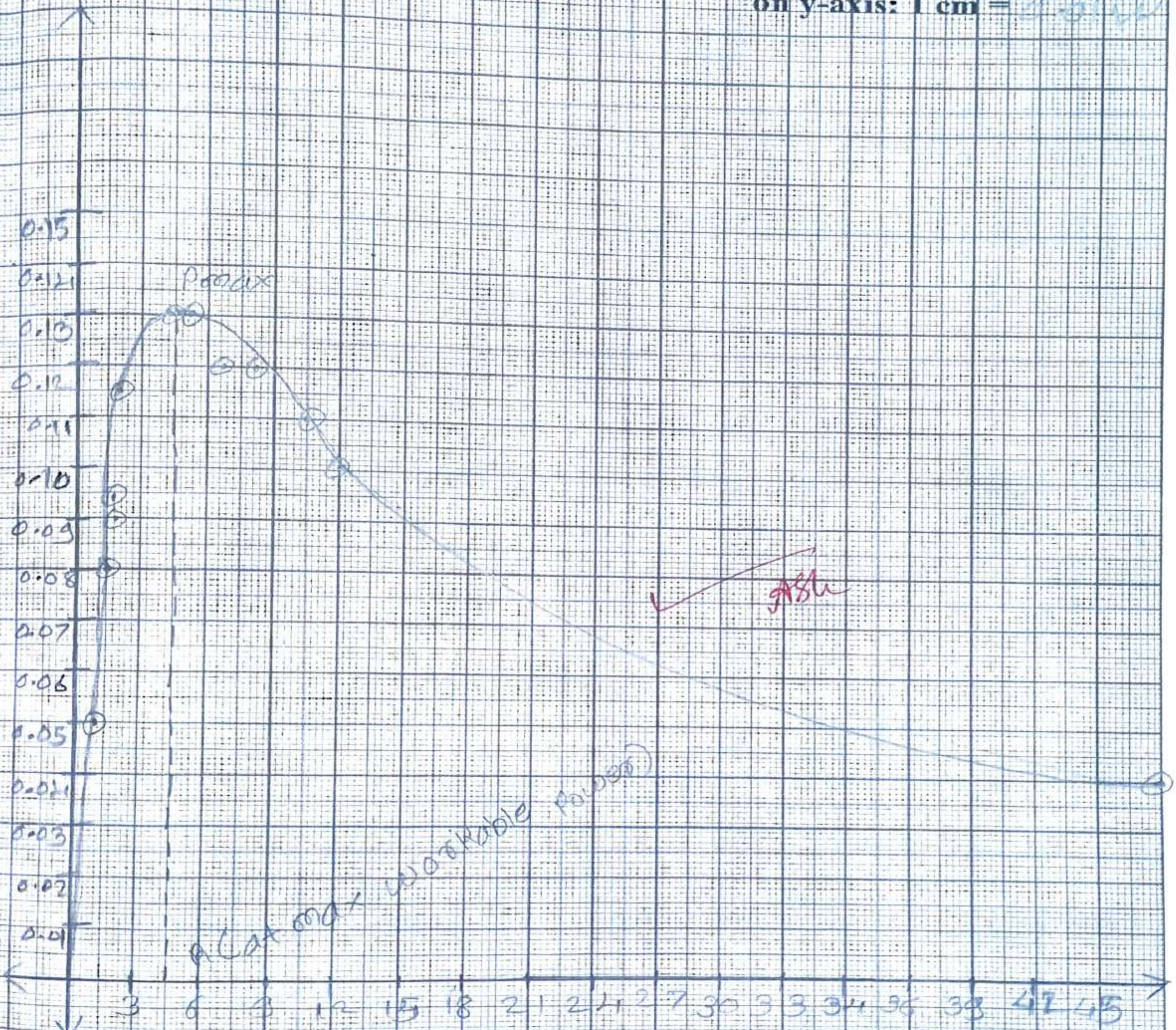
Scale

on x-axis: 1 cm = 3 Ω

on y-axis: 1 cm = 0.01 W



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Expt. No. 3 | Hall Effect

Aim: *To study the Hall-effect in semiconductor to determine,*

i) the type of semiconductor .

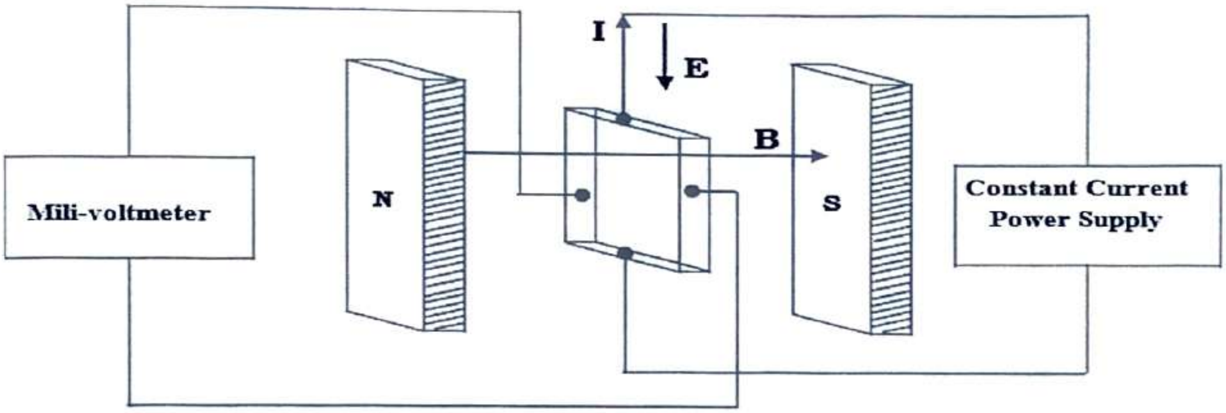
ii) Hall coefficient of a semiconductor.

iii) charge concentration.

iv) mobility of charge carriers.

Apparatus: *Hall-effect setup, Hall probe, electromagnet, constant current power supply, digital gauss meter etc.*

Diagram:

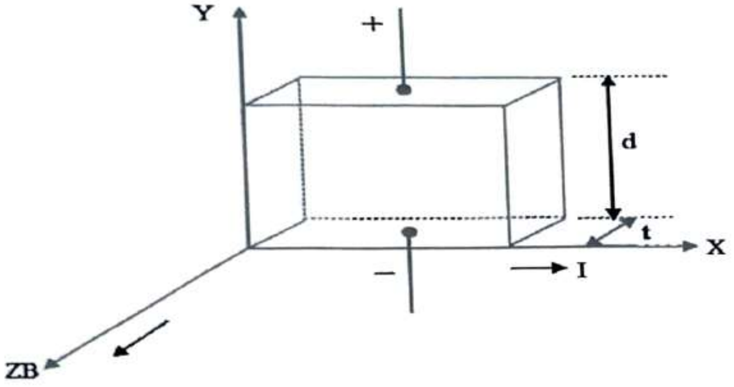


Theory:

Hall observed that, when a strip of metal carrying current was placed in a transverse magnetic field, a potential difference was developed across the strip perpendicular to both direction of current and the magnetic field. This effect is known as Hall effect.

It was later shown that, semiconductors also exhibits Hall effect, and the direction of electric field developed because of induced potential depends on whether the current is due to electrons or holes.

In order to understand Hall Effect consider a rectangular strip of n-type semiconductor material. Under the application of some potential difference, let current I flow through it along positive X-direction. Let the magnetic field B act along the positive Z-direction as shown in figure.



As the magnetic field is applied, the magnetic force acts along negative Y- direction. As the semiconductor is n-type, the charge carriers are electrons.

The magnitude of force is given by,

$$F_1 = B.e.v \tag*{1}$$

Where, $v = drift\ velocity$

$e = charge\ on\ electron$

Thus due to this force the electrons are forced to move in negative Y-direction and soon obstructed by the walls of specimen and get accumulated there. Because of charge accumulation towards side 1, it becomes negatively charged w. r. t. side 2. The electric field is developed between side 1 and side 2 directed along negative Y-direction. This electric field opposes further movement of electrons towards side 1. In equilibrium condition the force due to electric field is balanced to the force due to magnetic field and the current flows in the positive X-direction only. At this stage a steady potential difference is produced between side 1 and side 2 called as 'Hall Voltage', V_H.

Let E be the electric field intensity due to Hall Voltage then,

$$F_2 = e.E \tag*{2}$$

From equations (1) and (2) we get,

$eE = Bev$

Therefore,

$$E = B.v \tag{3}$$

But,

$$E = \frac{v_H}{d} \tag{4}$$

Where, d = distance between side1 & side 2.

From equations (3) and (4) we get,

$$\frac{v_H}{d} = B.v \quad or$$

$$V_h = B.e.d \tag{5}$$

We know that,

$$I = n.e.v.A$$

$$Therefore, \quad v = \frac{I}{n.e.A} \tag{6}$$

Therefore, Equation (5) becomes,

$$V_H = \frac{B.I.d}{n.e.A} = \frac{1}{n.e}\frac{B.I.d}{A} \tag{7}$$

Where, n= carrier concentration

A= cross sectional area of the strip

Now, I/A = J = Current density

Therefore,

$$V_H = \frac{1}{n.e}\frac{B.I.d}{A} = \frac{1}{n.e}B.J.d \tag{8}$$

where, n.e = charge density or charge per unit volume. and A = cross sectional area of the material = d.t

∴ d/A = 1/t

∴ Equation (7) can be written as,

$$V_H = \frac{1}{n.e}\frac{B.I}{t} \tag{9}$$

Here, V_H is positive at side 2 w. r. t. side 1 as we considered the conduction is due to electrons. (n-type semiconductor). If the side 2 is negative w. r. t. side 1 then the charge carriers are holes i.e. the semiconductor is p-type.

Thus measurement of Hall Voltage helps us to identify whether the given semiconductor is p-type or n-type.

In equation (9) B, I, t, and V_H can be measured and then the charge density n.e can be determined and from that the carrier concentration (n) can be determined.

In equation (9) the quantity 1/n.e is the property of the material of the specimen and is called as 'Hall coefficient' 'R_H'

$$R_H = \frac{1}{n.e} \tag{10}$$

∴ Equation (9) becomes,

$$V_H = R_H\frac{B.I}{t}$$

Therefore,

$$R_H = \frac{V_H.t}{B.I} \tag{11}$$

Here, $V_H = E.d$ From equation (3)

Therefore,

$$R_H = \frac{E.d.t}{B.I}$$

Also, $J = I/A = I/d.t$

Therefore, $d.t/I = 1/J$

$$R_H = \frac{E}{B.J} \tag{12}$$

Thus, Hall coefficient RH of a semiconductor material may be defined as electric field per unit surface current density due to unit transverse magnetic field.

We know that,

$$\sigma = n.e.\mu \qquad \because as\ R_H = \frac{1}{n.e} \qquad 13$$

$$\sigma = \frac{1}{R_H}\mu \qquad 14$$

Thus measurement of conductivity and Hall coefficient determines mobility of charge carriers.

Thus Hall Effect can be used to,

(a) determination of type of semiconductor
(b) determination of carrier concentration.
(c) determination of mobility of charge carriers.

Procedure:

1. Connect the width-wire contacts of Hall probe to the terminals marked ‘voltage’.
2. Without connecting the current terminals, the setup is switched on and zero adjustment is made. The unit is then switched off.
3. The length-wire contacts of Hall probe are connected to the ‘current terminals of the setup.
4. Now the Hall probe is placed in the air gap of the electromagnet. Power supply for the electromagnet is switched on and magnetic field is adjusted to the suitable value. Rotate the Hall probe till it is perpendicular to magnetic field. Hall voltage will be maximum for this position.
5. The current through the semiconductor is adjusted to a suitable value. Hall voltage and polarity are noted down.
6. Measure the Hall voltage as a function of current keeping the magnetic field as constant. Take ten observations.
7. Plot the graph of V_H against I at constant magnetic field. Calculate slope of the graph.

Observations:

1. Thickness of semiconductor wafer = t = ...5..... mm.
   = ..5×10^{-3}.. m.

2. *Resistivity* = ρ = ...0.1.... ohm.m.

Observation Table:

Magnetic field = B = ...100..... k gauss = .$100 \times 10^{3} \times 10^{-5}$. Wb/m²
= 1 wb/m²

Obs. No.	Current(I) mA	Voltage(V) mV
1.	0.3	−0.4
2.	0.6	−0.8
3.	0.9	−1.3
4.	1.2	−1.8
5.	1.5	−2.7
6.	1.8	−3.4
7.	2.1	−3.8
8.	2.4	−4.2
9.	2.7	−4.4
10.	3.0	−4.5
11.	3.3	−4.4
12.	3.6	−4.2
13.		
14.		

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Calculations:

1. Calculation of Hall coefficient:

$$R_H = \frac{t}{B}\left(\frac{V_H}{I}\right) = \frac{t}{B} \times slope\ of\ graph\ no.\ 1$$

$$= \frac{5 \times 10^{-3}}{1} \times 1.5 = 7.5 \times 10^{-3}\ m^3/C$$

2. Calculation of concentration of charge carriers:

$$n\ or\ p = \frac{1}{e \, . \, R_H} = \frac{10^{22}}{12} = 8.34 \times 10^{20}\ /m^3$$

3. Calculation of mobility of charge carriers:

$$\mu = \sigma R_H = \frac{1}{\rho} R_H = \frac{7.5 \times 10^{-3}}{0.1}$$

$$= 7.5 \times 10^{-2}\ m^2/V.sec$$

Results:

1. The polarity of Hall voltage is −Ve. Therefore the given semiconductor is of n type.
2. The value of Hall coefficient is 7.5×10^{-3} m³/C.
3. The concentration of majority carriers is found to be 8.34×10^{20} / m³.
4. The mobility of charge carriers is found to be 7.5×10^{-2} m²/V.sec.

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	1/12
6	6	8	20	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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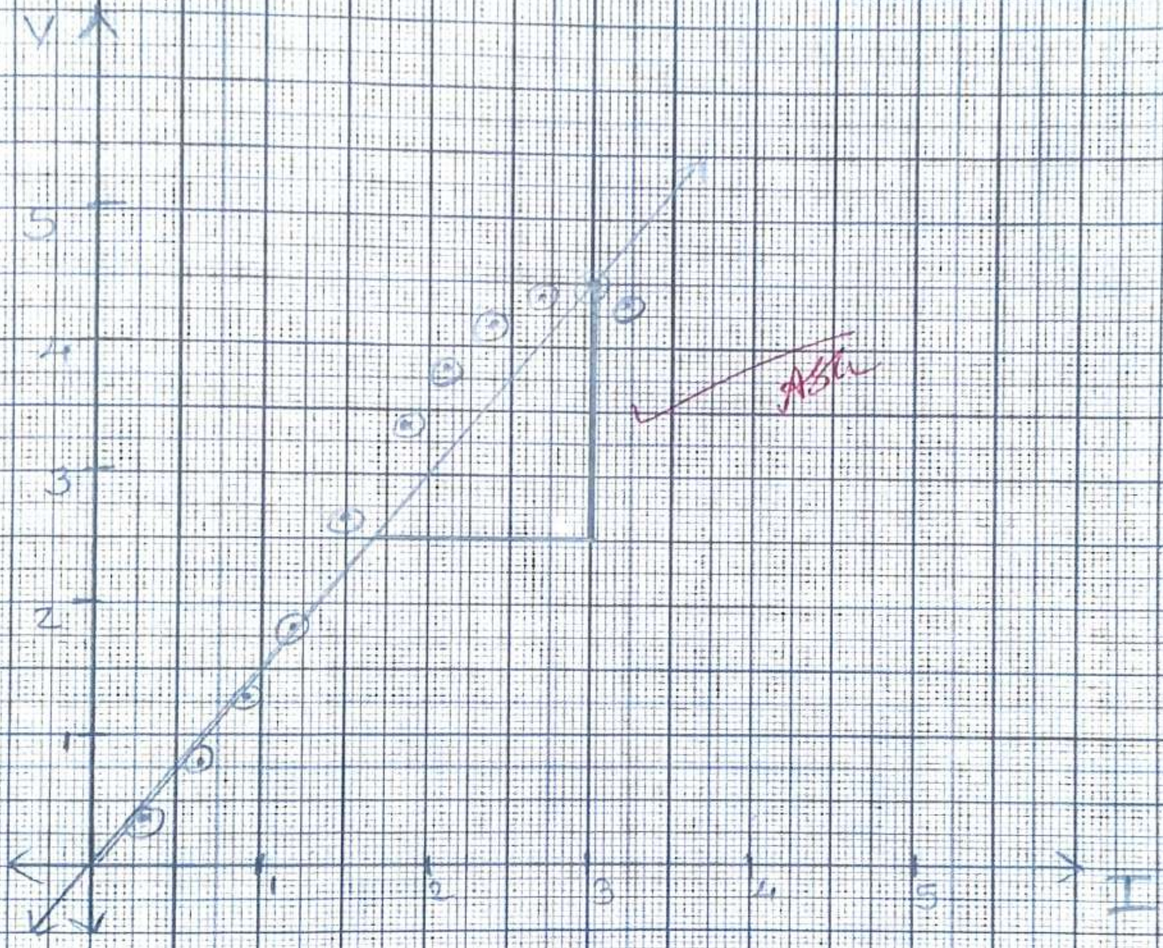
Scale

on x-axis: 1 cm = 0.5 mV

on y-axis: 1 cm = 0.5 mA

$$\text{Slope} = \frac{4.5 - 3}{3 - 2}$$

$$= \frac{1.5}{1} = 1.5$$



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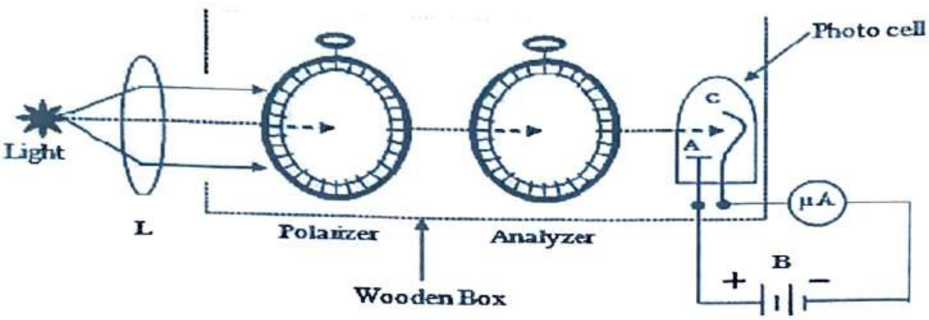
Expt. No. 4 | Malus Law

Aim: *To verify cosine square law of Malus for plane polarized light.*

Apparatus: *lamp, two Polaroid, Photo cell, micro-ammeter*

Experimental Arrangement:

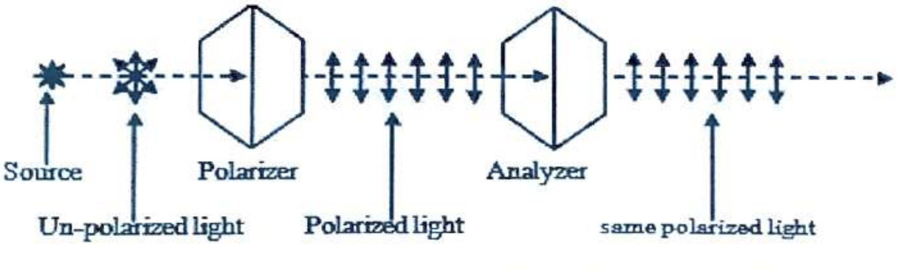


Theory:

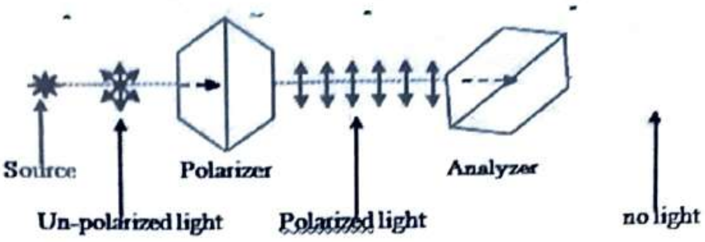
"Malus law states that, intensity of the polarized light transmitted through the analyzer varies as a square of cosine of angle between plane of transmission of polarizer and analyzer".

As Shown in the figure below the intensity of light transmitted by the analyzer is maximum when the angle between the plane of transmission of polarizer and analyzer is equal to zero (parallel arrangement) and it is minimum i.e. zero when that angle is equal to 90° (perpendicular arrangement).

Parallel arrangement of polarizer and analyzer: $\theta = 0^o$



Perpendicular arrangement of polarizer and analyzer: $\theta = 90^o$



Thus if, I = intensity of light transmitted by analyzer.

I_m = intensity of light transmitted by polarizer.

θ = angle between planes of polarizer and analyzer.

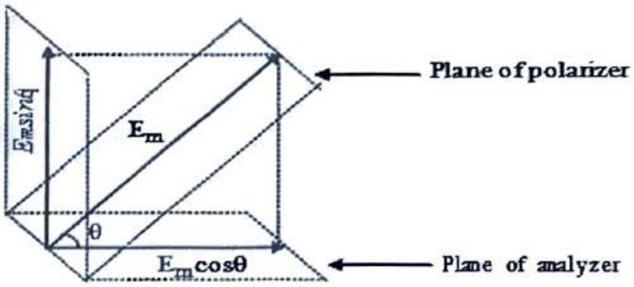
Then according to Malus law,

$$I \,\alpha \cos^2\theta$$

i.e. $I = I_m \cos^2\theta$

The proof of this law is based on the fact that polarized vibrations may be resolved into two rectangular components,

1. Parallel to the plane of transmission of analyzer.
2. Perpendicular to the plane of transmission of analyzer as shown in figure.



Let E_m = Amplitude of plane polarized light transmitted by the polarizer then it can be resolved into two components,

1. Em.cosθ. 2. Em.sinθ.

Only parallel component, $E_m.\cos\theta$ will be transmitted through the analyzer. Hence, intensity of light transmitted by the analyzer is,

$$I = (E_m \cos\theta)^2 = E_m^2 \cos\theta^2$$

i.e $\quad I = I_m \cos^2\theta$

Where, $I_m = (E_m)^2$ is the intensity of light transmitted through polarizer.

Procedure:

1. Adjust all the apparatus as shown in the experimental arrangement and keep the source, polarizer, analyzer and window of photo-cell at same height .
2. Switch ON the source and the power supply of the photo-cell. Adjust the polarizer and analyzer parallel to each other so that the micro-ammeter shows maximum reading. This means that the angle between plane of polarizer and analyzer is equal to zero.
3. Rotate the polarizer or analyzer in the steps of 10 degrees and record the corresponding value of current in the micro-ammeter.
4. Calculate the values of cos θ, $\cos^2\theta$ and $I/\cos^2\theta$. Plot the graph of I against $\cos^2\theta$.

Observation Table:

Sr. No.	**Angle through which analyzer is rotated θ (deg)**	**Current I (μA)**	**cos θ**	**$\cos^2\theta$**	**$\frac{I}{\cos^2\theta}$**
1.	0°	100	1	1	100
2.	10°	98	0.98	0.9604	102
3.	20°	92	0.94	0.8836	104
4.	30°	86	0.87	0.7569	113
5.	40°	78	0.77	0.5929	131
6.	50°	66	0.64	0.4096	161
7.	60°	52	0.5	0.25	208
8.	70°	39	0.34	0.1156	337
9.	80°	31	0.17	0.0289	1072
10.	90°	28	0		∞

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Result: The graph of I vs $\cos^2\theta$ is a straight line graph which verifies law of malus ($I \propto \cos^2\theta$).

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	Ash 1/1/22
6	6	8	20	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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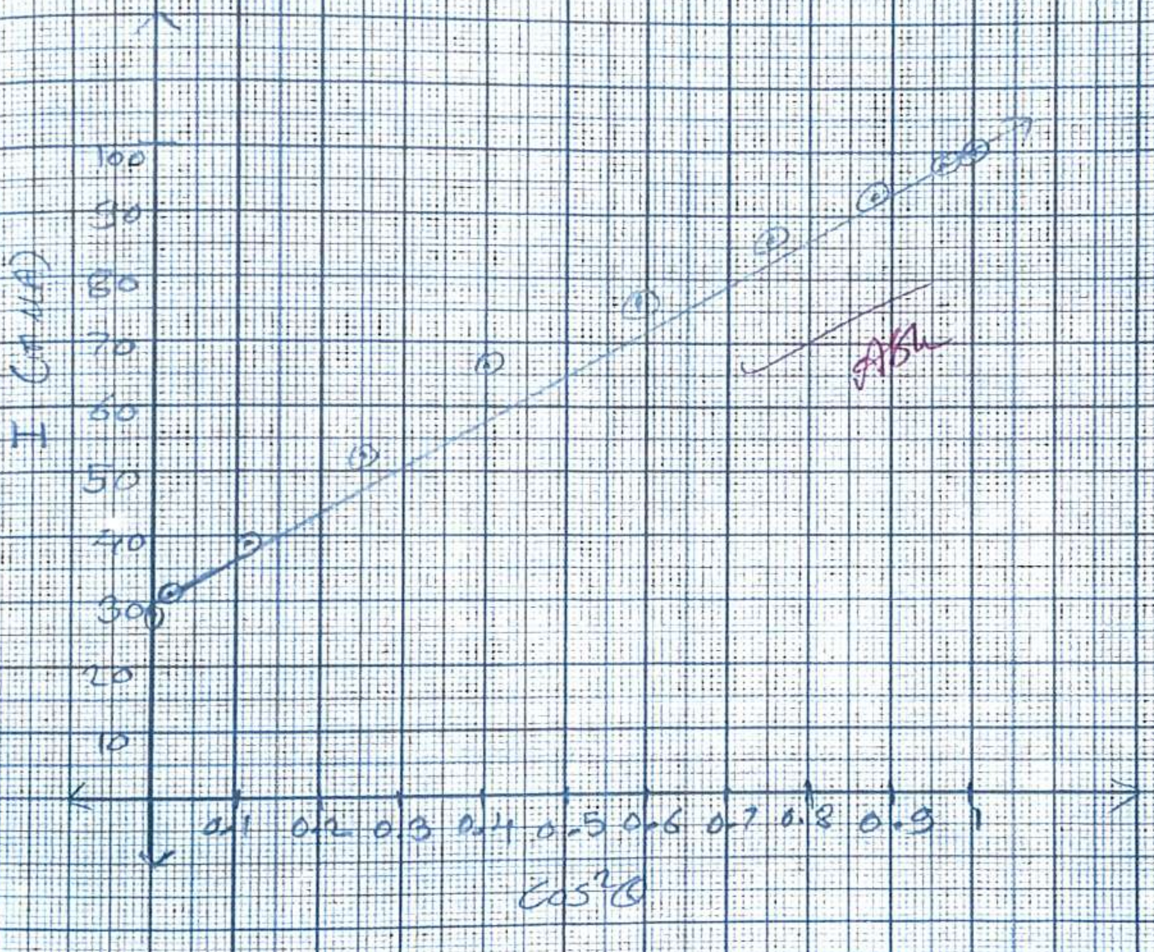
Scale

on x-axis: 1 cm = 10 μA

on y-axis: 1 cm = 0.1 unit



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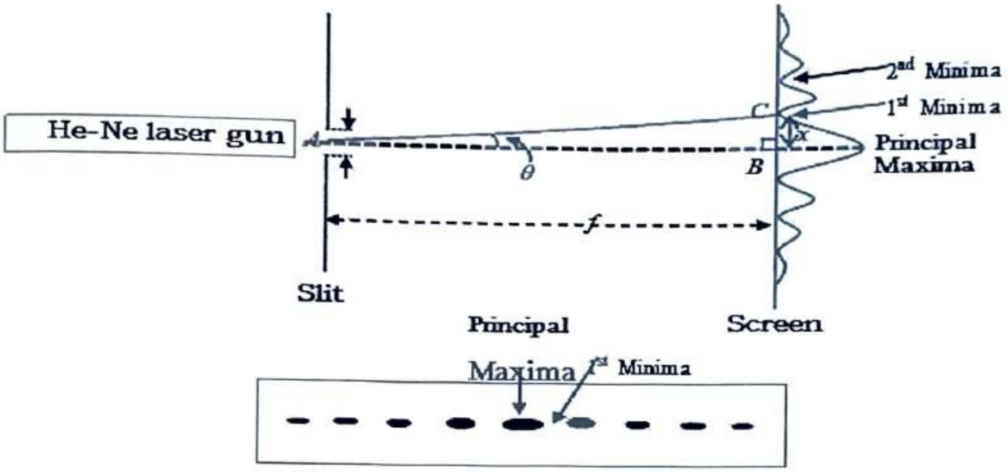
Expt. No. 5 He-Ne Laser

Aim: *To determine the width of a slit by using the diffraction pattern of He-Ne Laser.*

Apparatus: *He-Ne Laser, Thin wire, Screen, Scale etc.*

Diagram:



Diffraction pattern on the Screen

Theory:

For a single slit diffraction pattern the condition for minimum is,

$a\sin\theta = m\lambda$

Where, a= slit width

θ= angle of diffraction

λ= Wavelength of laser

m=Order of diffraction

For very small θ, $\sin\theta = \theta$ ∴ $a\sin\theta = m\lambda$

From right angle triangle ABC , $\theta = \frac{x}{f}$ ∴ $a.\frac{x}{f} = m\lambda$

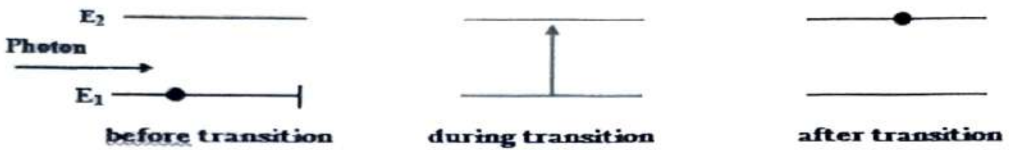
$\therefore a = \lambda f \frac{m}{x}$ This is the formula to determine the value of slit width.

LASER:

'LASER' stands for "Light Amplification by Stimulated Emission of Radiation". Laser is a quantum electronic device which produces very intense, unidirectional, monochromatic and coherent beam of light. Laser beam of visible light is highly parallel. For this reason, it can travel many miles without appreciable divergence.

Laser action:

When an atom absorbs energy it goes to higher energy states and it emits light during its transition from this excited higher energy state to the lower energy state.

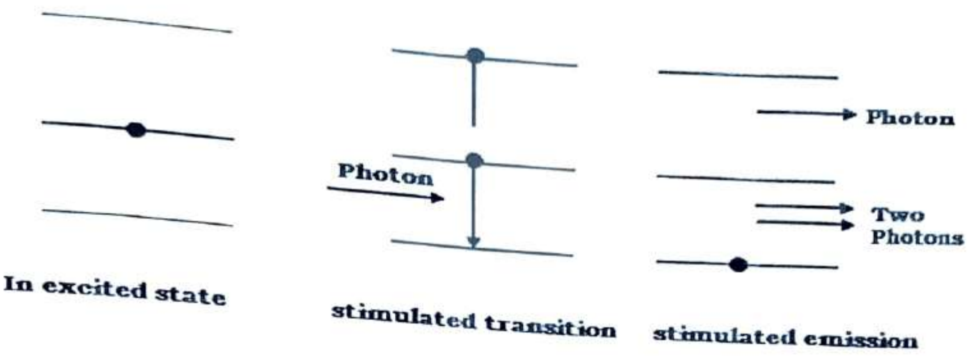


before transition **during transition** **after transition**

Fig. (a)

Consider two energy levels E_1 and E_2 ground and excited states respectively in an atom as shown in figure (a). If the atom is in lower state E_1 and when a photon of energy (E_2-E_1) strikes the atom, it goes in the excited state E_2 by absorbing the energy of photon. The atom can stay in the ground state for unlimited time. On the other hand atom can remain in a excited state for limited time, known as '***Life Time***'. Life time of excited H_2 atom is of the order of 10^{-8} seconds. However some of the excited states have longer life time of the order of 10^{-3} seconds. These states are called as '***Meta-stable States***'. These states play very important role in Laser operation.

Now in figure (b) the atom is in excited state E2 and there is no radiation nearby.After the life time of this state if the transition of an atom is allowed on its own accord spontaneously from level E_2 to level E_1. It emits a photon of frequency E_2-E_1/h. This is called as ***'Spontaneous Emission'.*** Spontaneous emission depends on the type of the atom and type of transition but is independent of outside circumstances. It is random in character. The radiation is random mixture of quanta having various wavelengths. The waves coincide nether neither in wavelength nor in phase. Thus radiation is in-coherent and has broad spectrum.



In addition to spontaneous emission there is another possibility as shown in figure (c).

This means that under the effect of another external photon an atom can pass from an excited state to lower state emitting photon not only spontaneously but also forced to it. When the atoms are in the excited energy level, emission is stimulated before spontaneous emission occurs. The absorption of incident photon causes two photons to be emitted, one by spontaneous and other by ***'stimulated emission'***. Both the photons travel in the same direction have the same frequency and phase i.e. they are coherent. The emission of two photons with an input of only one photon implies amplification.

The occurrence of spontaneous emission is directly proportional to the number of atoms in the specified energy level, whereas in stimulated emission the rate of occurrence is proportional not only to the number of atoms in the excited state but also number of incident photons.

Population Inversion:

The process of getting large number of atoms in excited state than lower level is called as 'population inversion'. If large number of atoms can be excited to upper energy levels then the probability of stimulated emission i.e. light amplification increases. The system in which population of higher energy state is more than population of lower energy state is called as ***'Negative Temperature State'***. Negative temperature state is not a physical quantity; it just indicates that the system is non-equilibrium.

When the atomic system interacts with photon it undergoes with the process of stimulated absorption, spontaneous emission as well as stimulated emission.

If, N_1 = Number of atoms in lower energy state E_1.

N_2 = Number of atoms in higher energy state E_2.

Normally, $N_1 > N_2$

If the photons of energy $h\nu = E_2 - E_1$ are incident on the atom, photons get absorbed and some of the atoms get excited to state E_2. This process of stimulated absorption depopulates level E_1.

The rate at which process occurs is expressed as,

$$R_{12} = p_a N_1 \tag{1}$$

Where P_a = probability of stimulated absorption.

Similarly, the stimulated emission depopulates energy level E_2 resulting in the emission of photons.

The rate at which process occurs is,

$$R_{21} = p_e N_2 \tag{2}$$

Where P_e = probability of stimulated emission.

At equilibrium, $P_a = P_e$.

Then comparing two rates in equation (1) and (2), it is observed that more energy is absorbed than emitted.

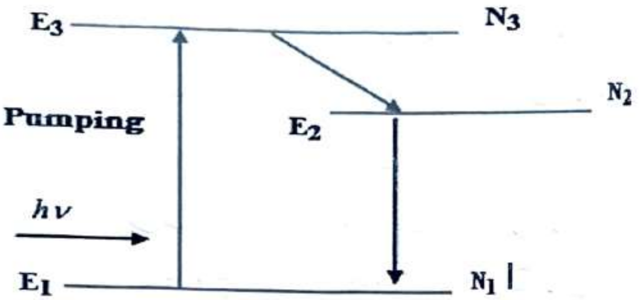
i.e. $P_a.N_1 > P_e.N_2$ $\qquad$ $N_1 > N_2$

To produce more emission it is essential to have $N_2 > N_1$. This is called as '***Population Inversion***'. The system in which population inversion is achieved is called as active system. The method of rising atoms from lower energy level to higher energy level is called as '***Optical Pumping***'.

Three level pumping system:

To achieve steady state population inversion a three level system is used as shown in figure below.

The three level systems consist of energy levels E_1, E_2 and E_3. Let N_1, N_2 and N_3 be the population densities of these levels respectively. In equilibrium, $N_1 > N_3$The pump lifts atoms from level E_1 to level E_3 from which they decay rapidly to level E_2 through some non-radiation process. If this non-radiation process is very fast between the levels E_3 and E_2, the electrons from level E_3 get transferred to level E_2 rather than return to level E_1.



Level E_2 is a meta-stable state with a longer life time. As a result the rate at which the atoms are pumped to level E_3 exceeds. The situation is raised where the number of atoms reaching and remaining in level E_2 exceeds than the number of atoms in level E_1. Thus population inversion is achieved. When electrons make transition from E_2 to E_1 radiations of frequency $(E_2-E_1)/h$ are given out.

Procedure:

1. Fix the wire, whose diameter is to be determined in the path of a laser beam and obtain the diffraction pattern on the screen in front of the laser gun.
2. Measure the distance f between the source (laser gun) and the screen.
3. Measure the distance of secondary maximum of different orders from the center on either side. Find the mean distance for each order.
4. Find the value of $(\chi_m - \chi_m')$ by using half table method and then find mean value of $(\chi_m - \chi_m')$.

Observations:

1. Wavelength of He-Ne Laser = λ = 6.328×10^{-8} cm.
2. Distance between the source and the screen = f = 100.6 cm

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Observation Table:

Obs. No.	Order m	Distance of order from center χ_m (cm.)		Mean distance χ_m (cm.)	$\chi_m - \chi_m'$ (cm.) By half table method	Mean $\chi_m - \chi_m'$ (cm.)
		Right	**Left**			
1.	1	0.6	0.5	0.55	2.9	2.75
2.	2	1.2	1.2	1.2	2.5	
3.	3	2	2	2	2.75	
4.	4	2.5	2.6	2.55	2.85	
5.	5	3.2	3.6	3.4		
6.	6	3.9	4	3.95		
7.	7	4.5	4.5	4.5		
8.	8	5.4	5.5	5.45		
Mean						

Calculations: $6328 \times 10^{-8} \times 100.6$

$a = \lambda f \left[\frac{m-m'}{|x-x'|} \right] = \times \left[\frac{4}{2.75} \right] = 9.23 \times 10^{-3}$ cm.

Result:

The width of a given slit is = 9.23×10^{-3} cm = 9.23×10^{-2} mm .

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	Ash 19/1
6	5	8	19	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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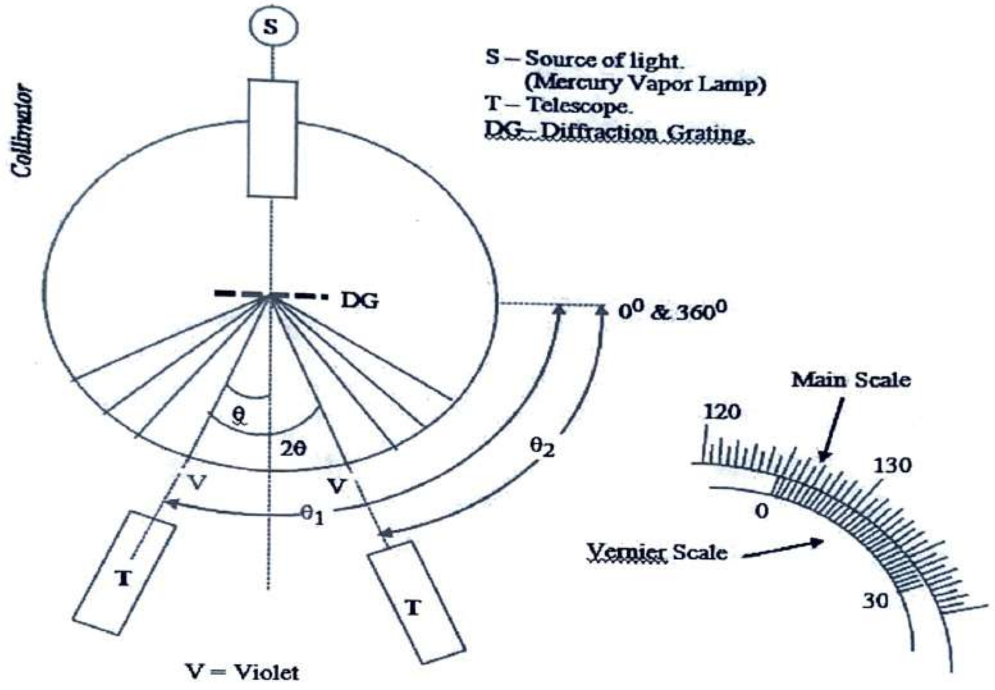
Expt. No. 6

Diffraction Grating

Aim: *To determine wavelength of light using diffraction grating.*

Apparatus: *Spectrometer, source of light (mercury lamp), diffraction grating, magnifying glass, reading lamp etc.*

Ray Diagram:



$$Least\ Count = \frac{Value\ of\ smallest\ division\ on\ M.S.}{Total\ number\ of\ divisions\ on\ V.S.}$$

$$Total\ Reading = M.S.R. + (V.S.R.\ \times\ L.C.)$$

Theory:

The aim of the experiment is one of the basic tasks in spectroscopy i.e. determination of wavelength of spectral lines. The distribution of dispersed radiated energy arranged periodically according to certain parameters like energy, frequency,

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wavelength etc. is called the spectrum. The source can be made to emit the radiation by suitably exciting it by direct or by electrical heating. The excited atoms remit the absorbed energy while returning to the ground state. This radiated energy can be converted into a spectrum using the spectrometer, mounted with suitable device like a prism or a diffraction grating. The spectrometer is an instrument used to produce, observe and analyze the spectrum of given source. It consists of a collimator, a spectroscopic device and a telescope.

The bending of light round the corners of an obstacle of dimension comparable to its wavelength is called diffraction. When waves encounter obstacle or small apertures whose dimensions are comparable with wavelength, they bend round the edges of corners of the obstacle or apertures. Such bending of waves around the obstacle is known as Diffraction.

Light travels in the form of waves; it also exhibits phenomena of diffraction. Diffraction is noticeable only when width of obstacle or aperture is comparable with wavelength of light. Since the wavelength of light is small, the diffraction effects usually go unnoticed; with special effect they become detectable.

The phenomenon of diffraction was successfully explained by Fresnel. Fresnel using Huygen's principle of secondary wavelets and principle of interference explained diffraction pattern produced by light. The diffraction effect is observed in the form of a pattern consisting of central bright ap

A diffraction grating consists of a large number of exactly parallel and equidistant slits. It is prepared by ruling equidistance lines on the glass with the help of diamond point. The line drawn acts as opaque space and between the two lines a slit are formed. The grating diffract the light wave of various wavelengths emitted by the source through different angles, thereby making it possible to determine the wavelengths. Grating is often used to measure wavelengths and to study the intensity of spectral lines. By letting white light fall on a grating, we obtain its spectrum. The central maximum in the pattern is white. The maximum on both sides of white line are arranged in order of increasing wavelength. The distance between the colored lines in the same spectrum is proportional to the difference in their wavelength.

Using mathematical analysis it can be shown that the principal maxima of order 'n' for a given grating lies at an angle 'θ' which satisfies the following condition.

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

Where, $(a+b)$ *grating element*
a = *Slit width*
b = *distance betweentwo adjacent slits*
n = *order of the spectrum*.

The source used in this experiment is a mercury vapor lamp, which is a source of white light. It contains vapors of mercury in which electric discharge is produced by applying high voltage. The mercury spectrum consists of a few lines in the ultraviolet region and four lines in the visible region.

Procedure:

1. Adjust the telescope and collimator for parallel rays by Schuster's method.
2. Mount the diffraction grating on the prism table such that its plane is perpendicular to the prism table.
3. Arrange the face of the grating so that it lies normal to the collimator.
4. Focus the vertical cross-wire of the eye-piece such that it passes through the center of red line of the first order spectrum on the left hand side. This focusing must be perfect for the accurate results.
5. Clamp the telescope and note its angular position using the angular scale through the observation window. This reading is left θ_1 for red color. Use a reading lamp and magnifying glass to note the reading.
6. Similarly, take readings of θ_1 for the other lines of the left spectrum in a sequence e.g. as, yellow, green,indigo and then violet.
7. Then turn the telescope to the right side spectrum and take the readings of θ_2 for the first order spectrum in a sequence opposite to the left spectrum. (First we are taking all left side readings a then all right side readings without moving the telescope in a zigzag manner because zigzag movement may introduce a parallax in the readings.)
8. Calculate 2θ,θ, sinq and therefore λ_{exp} for each color by using the given formula.

Observations:

1. Grating element $= (a+b) = \frac{2.54}{\text{Number of slits/inch}} = \frac{2.54}{15000}$

$= 1.6 \times 10^{-4}$ cm $= 1.6 \times 10^{-4} \times 10^{8}$ Å

2. Least count of spectrometer $= \frac{0.5^\circ}{30}$ degree / minute.

$= \frac{30'}{30} = 1' = 0.0167^\circ$

$= \frac{1}{60}$ dg/min

Observation table:

Color of Spectral line	Angular positions		$2\theta = \lvert\theta_1 - \theta_2\rvert$ (deg)	$\theta = \frac{2\theta}{2}$ (deg)	$\sin\theta$	$\lambda_{exp} = (a+b)\sin\theta$ (Å)
	Left θ_1 (deg)	Left θ_2 (deg)				
Red	147.668	184.518	36.85	18.425	0.3161	5057.6
Yellow	148.685	183.551	34.865	17.4325	0.2956	4793.6
Green	150.067	182.902	32.835	16.4175	0.2826	4521.6
Violet	154.117	177.618	23.501	11.7505	0.2057	3259.

Results:

1. Wavelength of **Red** Color = 5057.6 Å
2. Wavelength of **Yellow** Color = 4793.6 Å
3. Wavelength of **Green** Color = 4521.6 Å
4. Wavelength of **Violet** Color = 3259 Å

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	ASh 30/1
6	5	8	19	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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Expt. No. 7 | Band Gap Energy

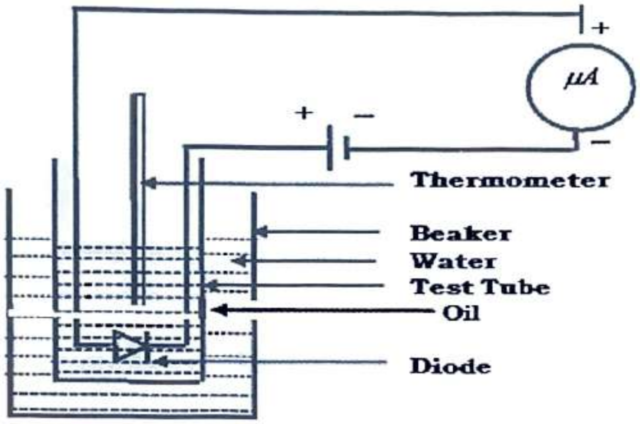
Aim: *To determine the Forbidden Energy Gap of a given semiconductor.*

Apparatus: *P-N junction diode, sand or oil bath, thermometer (100 °C), micro-ammeter (50 μA), D.C. Power supply, heater, etc.*

Formula:

$$E_g = \frac{\text{slope of graph } \log_{10} I_s \text{ Vs } \frac{10^3}{T}}{5.40}$$

Diagram:



Theory:

Solids are classified according to energy bands distribution. The band, which is occupied by valance electrons and has highest occupied band energy at absolute zero temperature is called valance band.

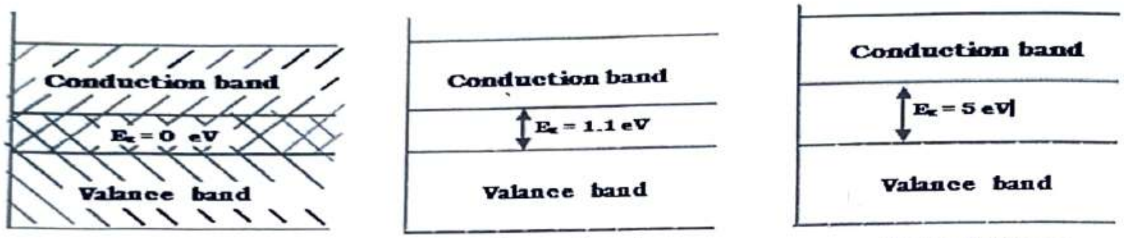
The lowest unfilled energy band at absolute zero temperature is called conduction band. Valance band and conduction band are separated by a gap known as forbidden energy gap (Eg). The electrons in valance band can be transferred to conduction band by providing them the energy equal to Eg. On the basis of forbidden energy gap, solids are classified into three groups, namely Conductors, Semiconductors, Insulators.

Eg = 0 eV in conductors,

$0 < Eg < 4$ eV in semiconductors

$Eg > 5$eV in insulators

Germanium ($Eg = 0.72$ eV) and silicon ($Eg = 1.1$ eV) are two good examples of semiconductors. In a semiconductor at absolute zero, the conduction band is empty and the valence band is filled. As temperature increases, the valence band electrons gain energy, and cross over the forbidden gap to move into the conduction band.



Conductors **Semiconductors** **Insulators**

As the number of electrons available for conduction increases with temperature, the resistivity of the semiconductor decreases and reverse saturation current increases. At temperature $T > 0$ K, we have,

$I_s = A * T^{3/2} \exp\left(\frac{E_g}{k_B T}\right)$ Where, I_s= reverse saturation current, k_B = Boltzmann's Constant, A= constant, T = Temperature in Kelvin, E_g = band gap energy of semiconductor.

For a small range of temperatures, the relation is expressed as,

$$\log_{10} I_s = constant - \frac{5.40 \times 10^3 \times E_g}{T}$$

$$\log_{10} I_s = constant - (5.40 \times E_g) \times \frac{10^3}{T} \quad y = c - mx \quad \text{with}$$

$$\log_{10} I_s = y\,; c = constant\,; m = slope = -(5.40 \times E_g) \;\&\; x = \frac{10^3}{T}$$

Therefore, $E_g = \frac{\text{slope of line}}{5.40}$

Procedure:

1. Measure voltage of given cell or battery.
2. Connect the diode in the reverse bias using given battery, connect the micro ammeter in this circuit to measure reverse bias current.
3. Deep the diode and thermometer in oil bath.
4. Start heating the oil bath by using heater or burner.
5. Apply 5 V constant voltage across the diode.
6. Note down the reverse saturation current at 30 °C and then increase the temperature with step size of 5 °C each, up to 65 °C and note down the corresponding current.
7. Plot the graph of l I_s Vs $10^3/T$. The nature of graph is straight line. Find the slope of the graph .
8. Substitute slope of graph in the given formula to find E_g in eV.

Observation Table:

D.C. Voltage (V) = ………1.5……… Volt

Obs. No.	Temp. (T) °C	I_s (μA)	T=(T+273) K	$\frac{10^3}{T}$ K^{-1}	$Log_{10}(I_s)$
1.	30	4	303	3.30	0.60
2.	35	6	308	3.24	0.77
3.	40	6	313	3.19	0.77
4.	45	8	318	3.14	0.90
5.	50	12	323	3.09	1.08
6.	55	16	328	3.04	1.20
7.	60	24	333	3.00	1.38
8.	65	36	338	2.95	1.55

Calculations:

We have,

$$E_g = \frac{\text{slope of graph } \log_{10} I_s \text{ Vs } \frac{10^3}{T}}{5.40} = \frac{3.33}{5.40} = 0.62 \; eV$$

Result:

The energy gap of given semiconductor diode is 0.62 *eV.*

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	29/12
6	6	8	20	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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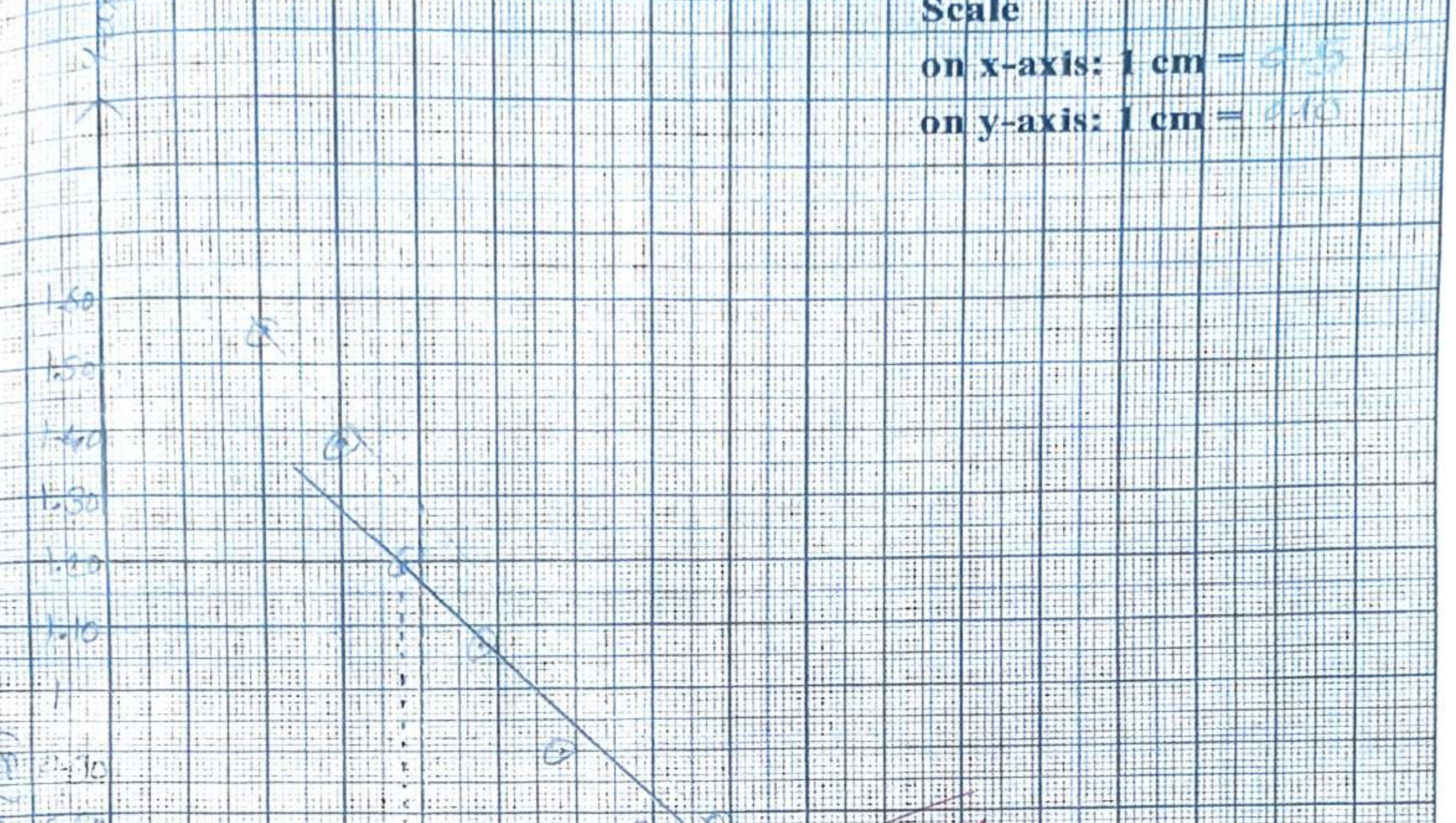
Scale
on x-axis: 1 cm = 0.5
on y-axis: 1 cm = 0.10



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Date of Performance: 22/12/2022

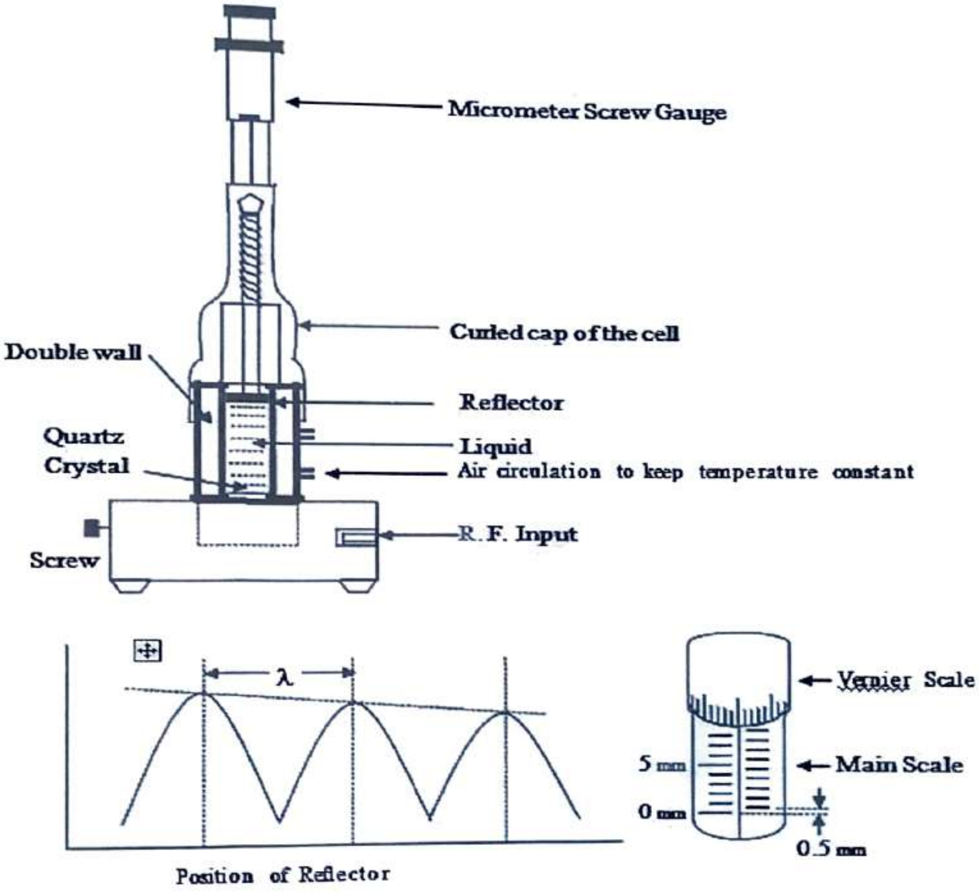
Expt. No. 8

Ultrasonic Interferometer

Aim: *To determine velocity of ultrasonic waves in a given liquid and hence compressibility of liquid by using ultrasonic interferometer.*

Apparatus: *Ultrasonic interferometer, liquid (distilled water), high frequency generator.*

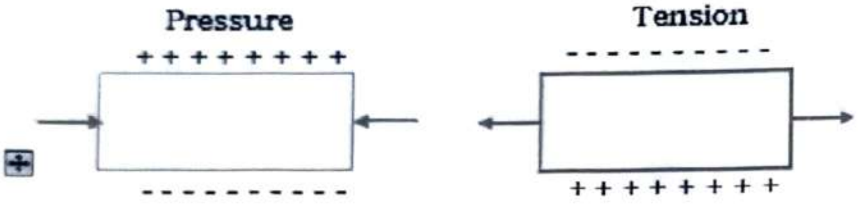
Diagram:



Theory:

The sound waves having frequency above audible range i.e. above 20000 Hz are called ultrasonic waves'. An ultrasonic interferometer offers a direct method to determine the speed of ultrasonic waves in liquids. The measurement is based on accurate determination of the wavelength of wave in the given medium. Ultrasonic waves of known frequency are produced by piezoelectric method.

Piezoelectric effect: In 1880, Curie brothers discovered that certain asymmetric crystals exhibits piezoelectric effect. In this effect, if one pair of opposite faces of a crystal is subjected to pressure then equal and opposite charges are developed on the other pair of opposite faces of the crystal. The converse of this effect is also true. According to this, if a potential difference is applied across two opposite pair of faces of a crystal, a change in dimensions of the crystal are observed in a direction perpendicular to these faces.



The polarity of charges get reversed when the faces are subjected to tension instead of pressure. If an alternating voltage is applied across a crystal it will alternately contract and expand and starts vibrating. If the frequency of applied AC voltage is adjusted equal to the natural frequency of vibration of a quartz crystal then resonance occurs and the crystal vibrates with maximum amplitude.

The frequency of vibration is given by,

$$n=\frac{1}{2l}\sqrt{\frac{Y}{\rho}}$$

Where, l = length of a crystal , Y = Young' s modulus of a crystal , ρ = density of a crystal.

In this experiment the quartz crystal is fixed at the bottom of the measuring cell, which is connected to the high frequency voltage generator. The ultrasonic waves produced from the quartz crystal are passed through liquid column in upward direction. The other end of the liquid column is closed by a reflector. The reflector can be moved in upward and downward direction by means of micrometer screw gauge attached to it. The displacement of the reflector can be measured on it. If the length of a liquid column is exactly whole multiple of the wavelength, standing waves are formed in the medium. This created an electrical reaction in the generator, which drives the quartz crystal. As a result, the anode current of the generator become maximum. The anode current becomes maximum if the length of liquid column is increased or decreased by $\lambda/2$ or a multiple of it. The velocity of ultrasonic waves can be calculated by calculating the value of wavelength.

Procedure:

1. Insert the cell in the square base socket and clamp it with the help of the screw provided.
2. Unscrew the cured cap of the cell and lift it away from the double wall. Pour the liquid in the cavity. Fix the curled cap such that the scale on the micrometer screw gauge is in front of the observer.
3. Connect the high frequency generator to the measuring cell using the cable provided.
4. For the initial adjustments two knobs are provided on the high frequency generator, one marked as 'Adj' and the other marked 'Gain'.
5. Switch ON the high frequency generator and wait for five minutes to warm it up. Initially, the needle of the ammeter goes to maximum, indicating that the ultrasonic waves are produced.
6. Adjust the needle to the neutral position, at 50 A, using adj knob. Keep the sensitivity, using Gain knob, such that the needle goes to 60 A.
7. Keep the micrometer on exactly 10 mm.
8. Now move the micrometer slowly in anticlockwise direction so that the reflector moves in upward direction and simultaneously carefully observe the ammeter scale. Whenever the condition $d=n\lambda/2$ is satisfied, the current will be at its peak value and the ammeter show maximum deflection of the needle. Stop moving the reflector at this stage and note the reading on the micrometer screw gauge as d_1. (First reading).
9. Continue rotating micrometer screw gauge. Every time the instrument satisfies the above condition, the ammeter needle shows maximum deflection. Continue rotating the screw and simultaneously count the chosen 'n' number of deflections. (e.g. 5 deflections = 5 resonance). Stop immediately after the 'n' number of deflections. Note down the micrometer screw gauge as d_2.
10. Calculate the speed of ultrasonic wave using the given formula.
11. Repeat the procedure for next 'n' number of deflections (resonance). The d_2 reading of the previous reading is d1 for the next and so on.
12. Take 10 readings and calculate speed of ultrasonic wave for each reading. Finally find out the mean value of the speed and write down as a result.

Observations:

1. Liquid used = Distilled water
2. Frequency of applied voltage = 2 x 10^6 Hz.
3. Least count of micrometer screw gauge = 0.01 mm.
4. Density of liquid = ρ = 996.45 kg/m^3.

Observation Table:

Obs. no.	No. of deflections (n)	Micrometer Screw gauge reading		d = $\lvert d_1 - d_2 \rvert$ (mm.)	d (m)	$\lambda = \frac{2d}{n}$	$v = f.\lambda$ m/sec
		d_1 (mm)	d_2 (mm)				
1.	5	0	2.15	2.15	2.15×10^{-3}	0.86×10^{-3}	1720
2.	10	2.15	4.03	1.88	1.88×10^{-3}	0.38×10^{-3}	760
3.	15	4.03	5.9	1.87	1.87×10^{-3}	0.25×10^{-3}	500
4.	20	5.9	7.44	1.54	1.54×10^{-3}	0.154×10^{-3}	308
5.	25	7.44	9.32	1.88	1.88×10^{-3}	0.15×10^{-3}	300
6.	30	9.32	11.19	1.87	1.87×10^{-3}	0.12×10^{-3}	240
7.	35						
8.	40						
9.	45						
10.	50						
						Mean Speed (v)	

Calculation:

The compressibility of the given liquid is given by ,

$$\beta = \frac{1}{\rho v^2} = \frac{1}{1000 \times (638)^2}$$

$$= 2.46 \times 10^{-9} \frac{ms^2}{Kg}$$

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Results:

1. The speed of ultrasonic waves in the given liquid is, 638 × 10^3 mm/s = 638 m/s
2. The compressibility of the given liquid is = 2.46 × 10^{-9} $\frac{ms^2}{Kg}$

Marks (out of 20)				Signature of teacher in-charge
MR (6)	MP (6)	MU (8)	Total	22/12
6	6	8	20	
MR-Marks for regularity, MP- Marks for Presentation, MU-Marks for understanding				

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Department of Electronics & Telecommunication Engineering

Vision

Department of Electronics & Telecommunication Engineering shall continue to innovate and practice the processes to propel development in engineering education, keeping excellence in focus and render services to match the needs of technical education system, industry and society.

Mission

To create an ambience and provide broad based education where students are urged to develop new ideas and professional skills in equilibrium with the needs of the nation.

PROGRAM EDUCATION OBJECTIVES (PEOs)

I. To sustain holistic development of students to pursue higher studies, successful entrepreneurship or cater needs of Indian and multinational industries, by providing excellent academic environment.

II. To develop students with solid foundation in mathematical, scientific and engineering fundamentals to solve engineering problems.

III. To nurture students with comprehensive knowledge and skills, to design & develop electronic systems for real life problems.

IV. To inculcate in students effective communication skills, teamwork skills, professional – ethical attitudes and cultivating ability in engineering issues through multidisciplinary domain to broader social context.

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Department of Electronics & Telecommunication Engineering

Class –B.E. (E & TC)
Subject: VLSI Design &Technology

Practicals: 2Hrs/Week

Practical: 50 Marks

List of Experiments

Sr. No.	Title of Experiment
	Part A: To write VHDL code, simulate with test bench, synthesis, implement on PLD (Any 5 to be performed)
01	4-bit ALU for Add, Subtract, AND, NAND, OR, XOR & XNOR.
02	Universal shift register with mode selection input for SISO, SIPO, PISO, & PIPO.
03	MOD N Counter
04	Keypad interface
05	FIFO memory
06	LCD Interface
	Part B: To prepare CMOS layout in selected technology, simulate with & without Capacitive load, comment on rise & fall times. (Any 3 to be performed)
01	Inverter, NAND, NOR gates
02	Half Adder & Full Adder
03	2:1 Mux using logic gates & transmission gates
04	One bit SRAM Cell
	Virtual Lab: 1. https://vlsi-iitg.vlabs.ac.in (Digital VLSI Design Lab.) 2. https://cse14-iiith.vlabs.ac.in/ (VLSI Lab.)

Dr.N.R.Dhumale
Prof.J.A.Desai
Prof.G.A.Thakur
Prof. S. H. Barshikar
(Subject Teachers)

Dr. P. M. Bangare
(Lab In-charge)

Dr. M. B. Mali
HOD(E&TC)

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EXPERIMENT NO. – 1

TITLE: To study VLSI Design flow using an EDA Tool

NAME OF THE STUDENT: Shreya Aigalikar

ROLL NO: 404C003

DATE OF PERFORMANCE: 22/7/22

DATE OF SUBMISSION: 29/7/22

SIGNATURE:

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EXPERIMENT NO.-1

Aim: To study VLSI Design Flow using an EDA Tool

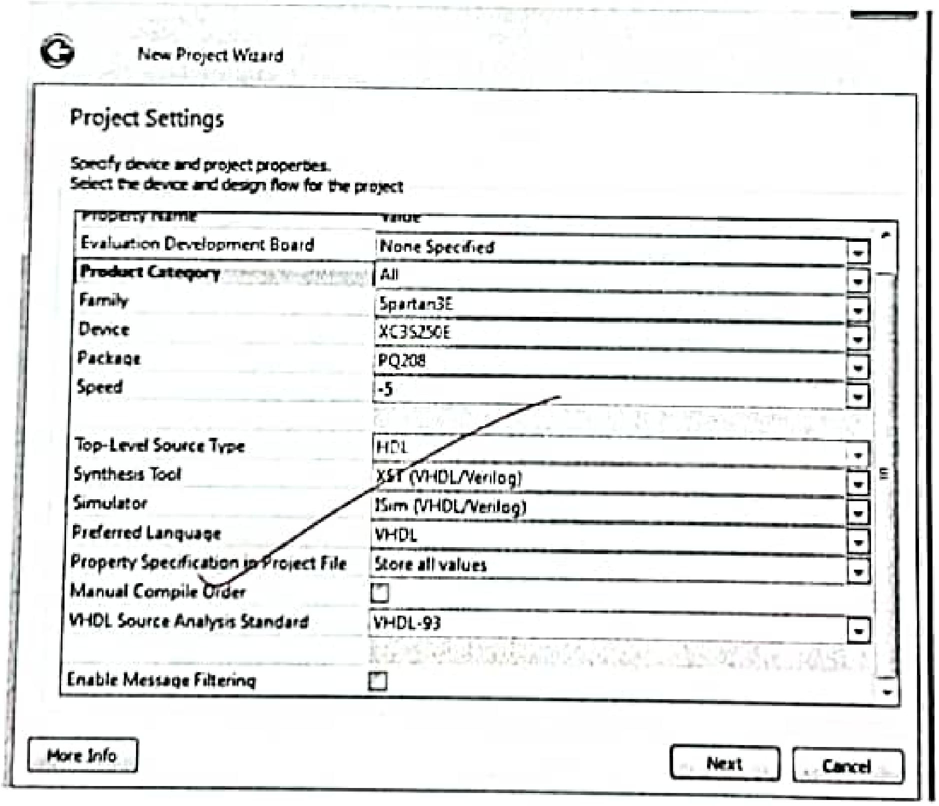
Theory:

Explain VLSI Design Flow

Procedure: -

1. Create a New Project

Create a new ISE project which will target the FPGA device on the Spartan-3E development board with following settings,



Project Settings

Specify device and project properties.
Select the device and design flow for the project

Property Name	Value
Evaluation Development Board	None Specified
Product Category	All
Family	Spartan3E
Device	XC3S250E
Package	PQ208
Speed	-5
Top-Level Source Type	HDL
Synthesis Tool	XST (VHDL/Verilog)
Simulator	ISim (VHDL/Verilog)
Preferred Language	VHDL
Property Specification in Project File	Store all values
Manual Compile Order	☐
VHDL Source Analysis Standard	VHDL-93
Enable Message Filtering	☐

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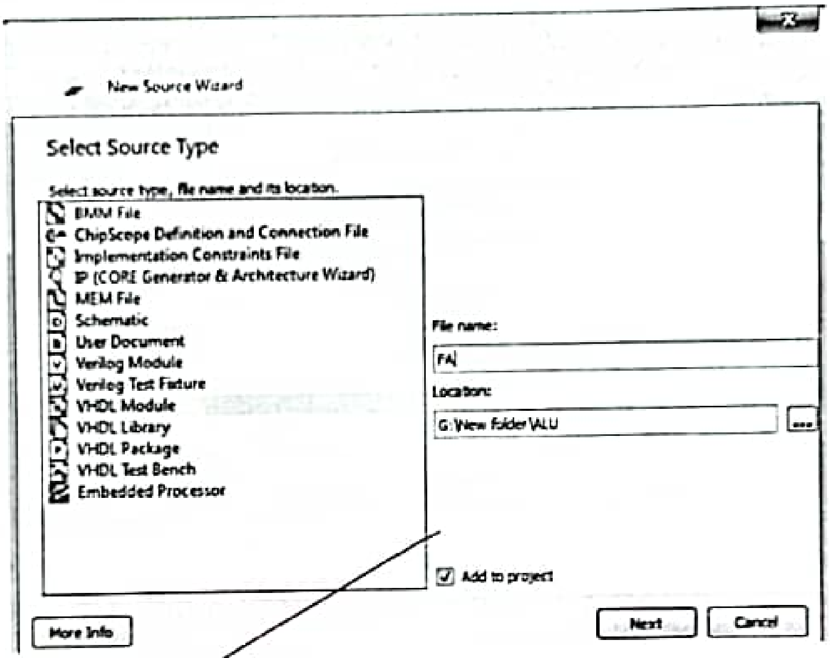
2. Click **Next** to proceed to the Create New Source window in the New Project Wizard.

At the end of the next section, your new project will be complete.

Create a VHDL source file for the project as follows:

1. Click the **New Source** button in the New Project Wizard.
2. Select **VHDL Module** as the source type.
3. Type in the file name **FA**.
4. Verify that the **Add to project** checkbox is selected.

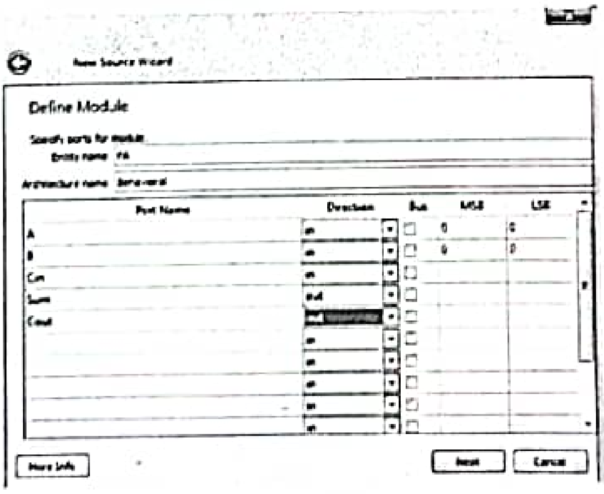


File name: FA

Location: G:\New folder\ALU

☑ Add to project

3. Declare the ports for the design by filling in the port information as shown below



Port Name	Direction	Bus	MSB	LSB
A	in	☐	0	0
B	in	☐	0	0
Cin	in	☐		
Sum	out	☐		
Cout	out	☐		

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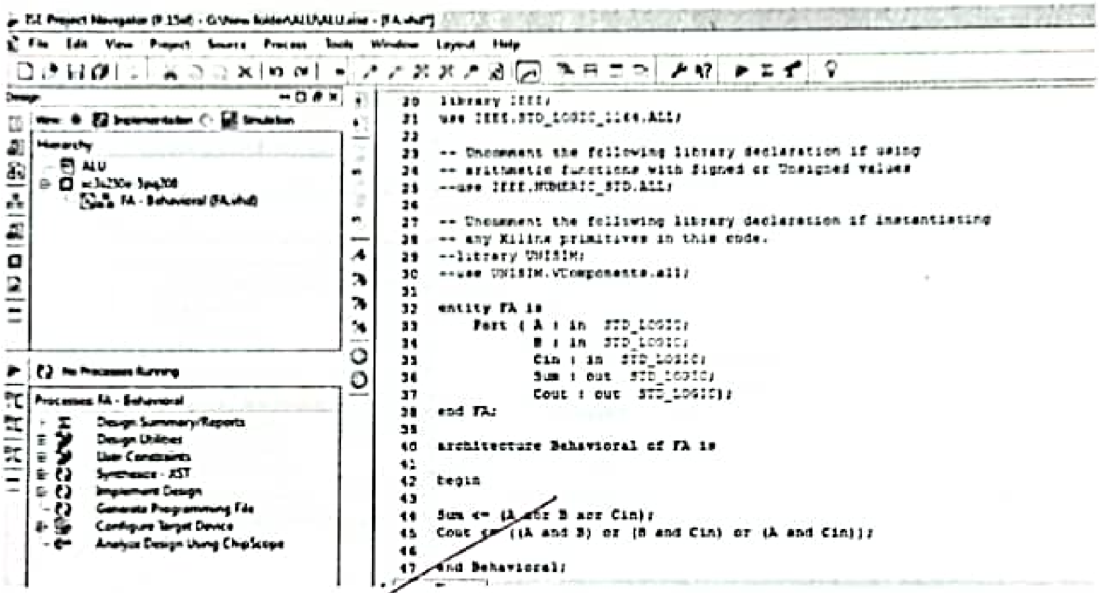
- Click **Next**, then **Finish** in the New Source Information dialog box to complete the new source file template.
- Click **Next**, then **Next**, then **Finish**.
- The source file containing the entity/architecture pair displays in the Workspace, and the **FA** displays in the Sources tab.
- Modify architecture to include Full adder logic.



```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values
--use IEEE.NUMERIC_STD.ALL;

-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

entity FA is
    Port ( A : in  STD_LOGIC;
           B : in  STD_LOGIC;
           Cin : in  STD_LOGIC;
           Sum : out  STD_LOGIC;
           Cout : out  STD_LOGIC);
end FA;

architecture Behavioral of FA is

begin

Sum <= (A xor B xor Cin);
Cout <= ((A and B) or (B and Cin) or (A and Cin));

end Behavioral;
```

4. Checking the Syntax of the 'FA' Module

When the source files are complete, check the syntax of the design to find errors.

1. Verify that **Implementation** is selected from the top list in the Sources window.
2. Select the **FA** design source in the Sources window to display the related processes in the Processes window.
3. Click the "+" next to the Synthesize-XST process to expand the process group.
4. Double-click the **Check Syntax** process.

Note: You must correct any errors found in your source files. You can check for errors in the Console tab of the Transcript window. If you continue without valid syntax, you will not be able to simulate or synthesize your design.

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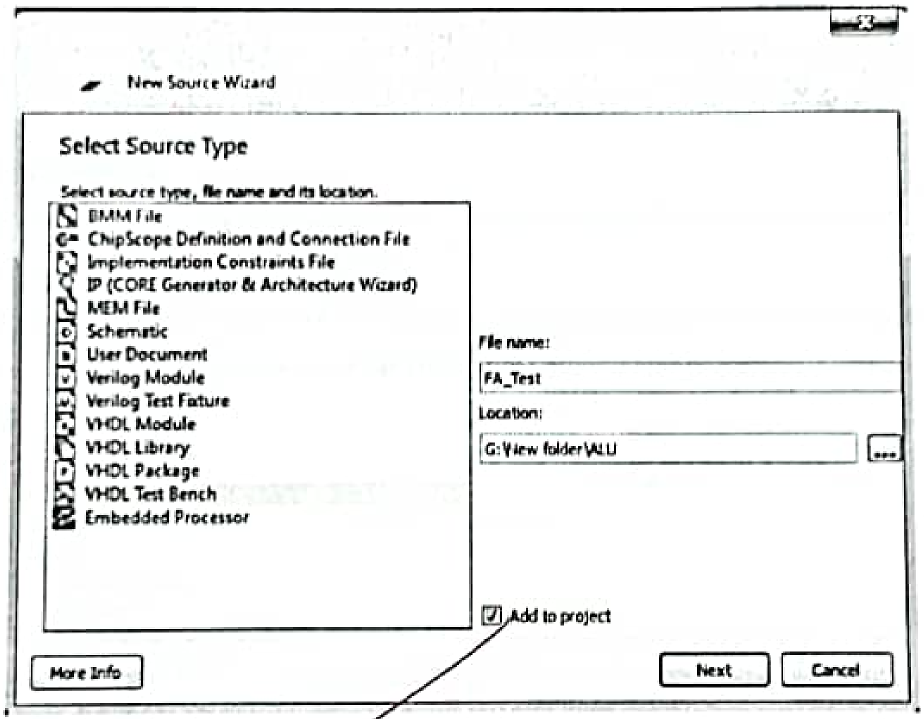
5. Design Simulation

Verifying Functionality using Behavioral Simulation

1. Verify that **Behavioral Simulation** is selected from the top list in the Sources window.
2. Select the **FA** design source in the Sources window to display the related processes in the Processes window.
3. Create New Source for test bench.



Select source type, file name and its location.

File name: FA_Test

Location: G:\New folder\ALU

☑ Add to project

- Write Testbench and Save it.
- Select the FA_Test testbench source in the Sources window to display the related processes in the Processes window.
- Click the "+" next to the **ISim Simulator** process to expand the process group.
- Double-click the **Simulate Behavioral Model** process.
- It will invoke **ISim Simulator** Tool and will open Signals and Wave windows.

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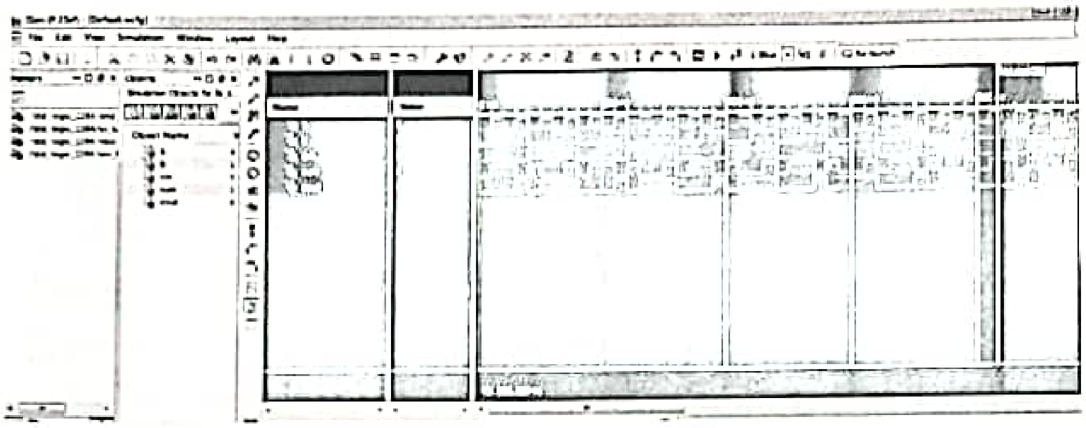
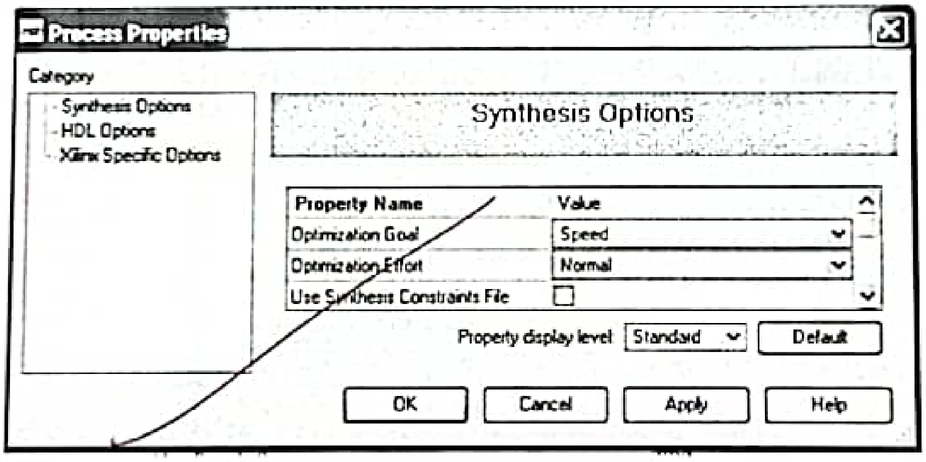


6. Design Synthesis

1. Verify that **Synthesis/Implementation** is selected from the drop-down list in the Sources window.

2. Select the **FA** design source in the Sources window to display the related processes in the Processes window. Right Click on **Synthesize-XST** then select properties. Give **Synthesis Options**, then click Ok.



Process Properties

Category
- Synthesis Options
- HDL Options
- Xilinx Specific Options

Synthesis Options

Property Name	Value
Optimization Goal	Speed
Optimization Effort	Normal
Use Synthesis Constraints File	☐

Property display level: Standard

3.Double Click on **Synthesize-XST**

4. Notice that after Implementation is complete, the Implementation processes have a green check mark next to them indicating that they completed successfully without Errors or Warnings.

5.If synthesis is successful view RTL schematic, Technology schematic and synthesis report(Focus on Final report) by clicking in respective process. Shown below.

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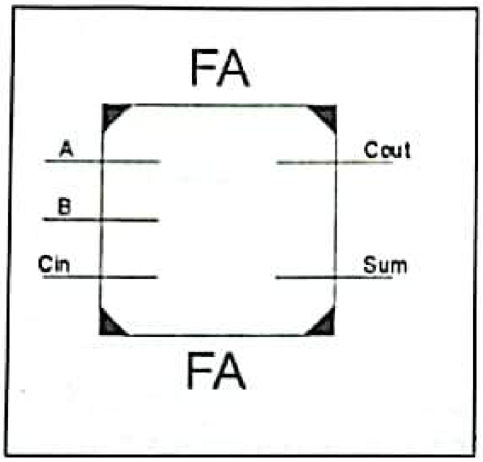
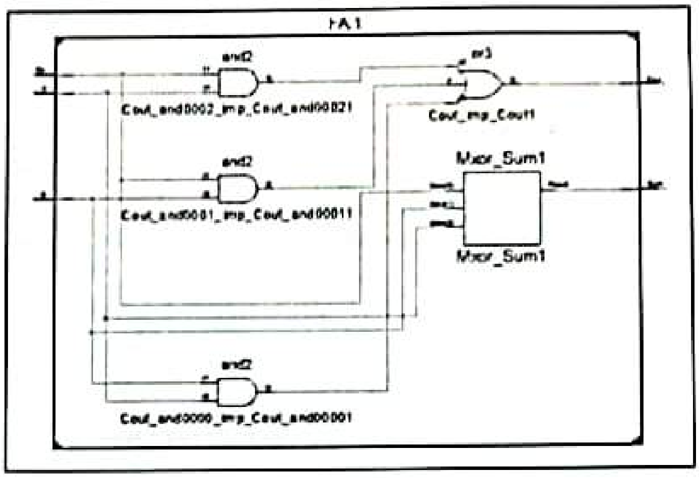
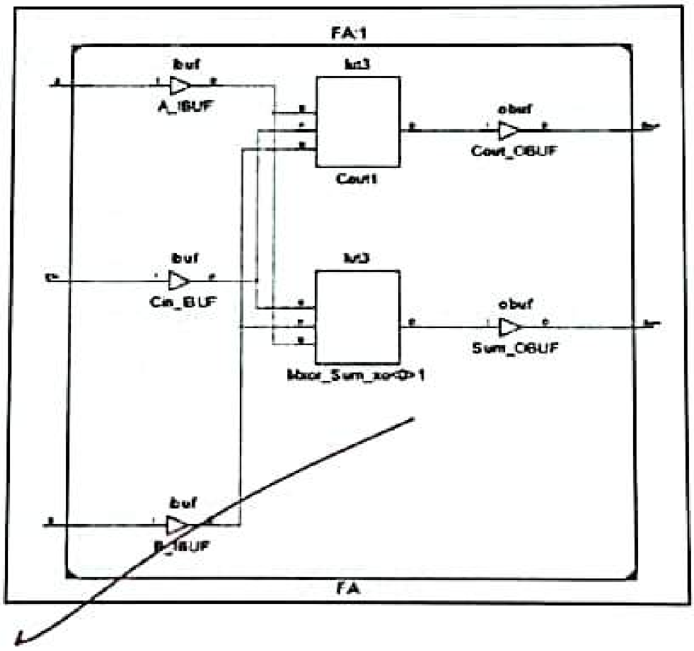
RTL Schematic





Technology Schematic



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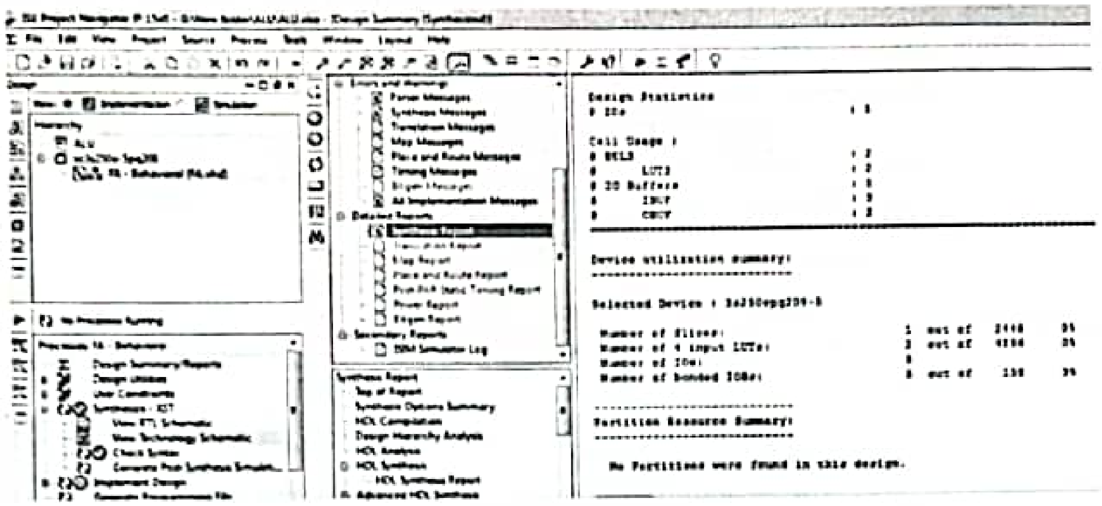
Study Final report of Synthesis



```
Design Statistics
# IOs                                  : 5

Cell Usage :
# BELS                                 : 2
#      LUT3                            : 2
# IO Buffers                           : 5
#      IBUF                            : 3
#      OBUF                            : 2

Device utilization summary:
---------------------------

Selected Device : 3s250epq208-5

 Number of Slices:                       1  out of   2448     0%
 Number of 4 input LUTs:                 2  out of   4896     0%
 Number of IOs:                          5
 Number of bonded IOBs:                  5  out of    158     3%

---------------------------
Partition Resource Summary:
---------------------------

  No Partitions were found in this design.
```

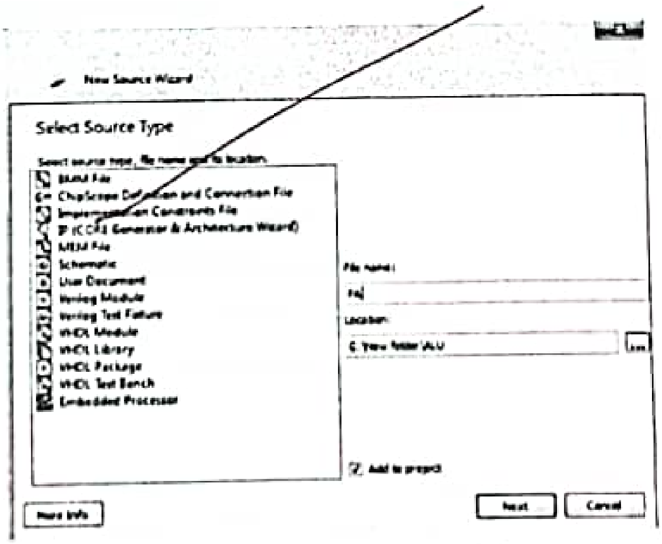
6. Design Implementation,

Assigning Pin Location Constraints

Specify the pin locations for the ports of the design so that they are connected correctly on the FPGA Board.

To constrain the design ports to package pins, do the following:

1. Verify that FA is selected in the Sources window.
2. Create (.ucf file) by clicking **create source->select Implementation Constraints File, file name FA -> next-> next -> finish**



File name: FA

Location: E:\New folder\ALU

☑ Add to project

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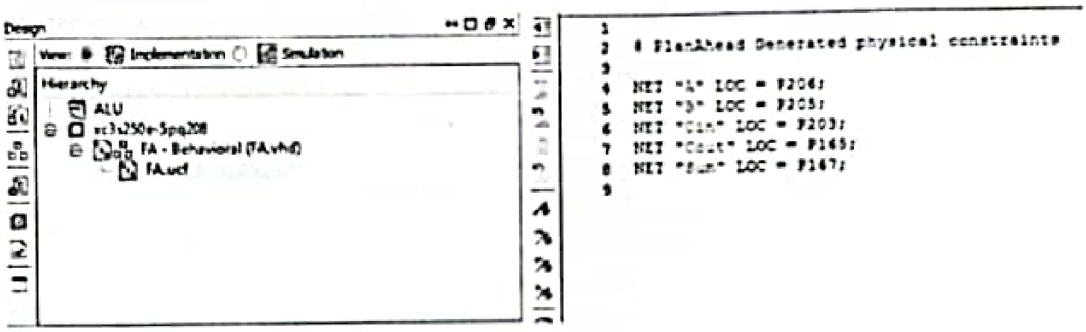
Add pin assignments in UCF file



```
# PlanAhead Generated physical constraints

NET "A" LOC = P206;
NET "B" LOC = P205;
NET "Cin" LOC = P203;
NET "Cout" LOC = P165;
NET "Sum" LOC = P167;
```

Design Implementation

1. Verify that **Implementation** is selected from the top list in the Sources window.

2. Select the **FA** design source in the Sources window to display the related processes in the Processes window. Double click on **Implement Design.**

3. Notice that after Implementation is complete, the Implementation processes have a green check mark next to them indicating that they completed successfully without Errors or Warnings.

4. Open the Design Summary by double-clicking the **View Design Summary** process in the Processes window.

7. Procedure for FPGA configuration (downloading bit file)

1. Device details, Sparten 3E XC3S-250E, package PQ208, Speed grade -4
2. After successful simulation, modify code for clock divider logic if applicable
3. Synthesis
4. Assign package pins
5. Implementation
6. Generate program file (.bit)
7. Install device drivers : JTAG & Serial Port
8. Copy batch & log file to project location
9. Open batch file-> change bit file name batch file text
10. Run

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Observation & Results:

Attach following.

1. VHDL Design
2. VHDL Testbench
3. Simulation Result
4. Schematics(RTL, Technology)
5. UCF File

Conclusion:

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```
----------------------------------- Code ------------------------------------------
-- Name: Ruchika Suresh Suryawanshi
-- Roll No: 404A060
-- Experiment No. 1: To Study VLSI Design flow using an EDA Tool.
-----------------------------------------------------------------------------------
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity be_a4_and_vhdl is
  Port ( A : in  STD_LOGIC;
        B : in  STD_LOGIC;
        Y : out  STD_LOGIC);
end be_a4_and_vhdl;

architecture Behavioral of be_a4_and_vhdl is

begin
Y<= A AND B;

end Behavioral;
```

```
----------------------------------- Test Bench ------------------------------------------
-- Name: Ruchika Suresh Suryawanshi
-- Roll No: 404A060
-- Experiment No. 1: To Study VLSI Design flow using an EDA Tool.
------------------------------------------------------------------------------------------
LIBRARY ieee;
USE ieee.std_logic_1164.ALL;

ENTITY BE_A4_AND_A4 IS
END BE_A4_AND_A4;

ARCHITECTURE behavior OF BE_A4_AND_A4 IS

        -- Component Declaration for the Unit Under Test (UUT)
        COMPONENT be_a4_and_vhdl
                PORT(   A : IN  std_logic;
                        B : IN  std_logic;
                        Y : OUT  std_logic);
        END COMPONENT;

        --Inputs
        signal A : std_logic := '0';
        signal B : std_logic := '0';

        --Outputs
        signal Y : std_logic;

        BEGIN
```

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```
-- Instantiate the Unit Under Test (UUT)
  uut: be_a4_and_vhdl PORT MAP (
       A => A,
       B => B,
       Y => Y
      );

-- Stimulus process
stim_proc: process
begin
         A<='0';
        B<='0';
         -- hold reset state for 100 ns.
        wait for 100 ns;
        A<='0';
        B<='1';
        wait for 100 ns;
        A<='1';
        B<='0';
        wait for 100 ns;
        A<='1';
        B<='1';
        wait;
end process;

END;
```

24/7/22

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Sinhgad College of Engineering
Vadgaon (Bk), Pune 411 041

STES's

SINHGAD COLLEGE OF ENGINEERING

Vadgaon(Bk), Pune

Department of Computer Engineering

LABORATORY MANUAL

2022-23

OBJECT ORIENTED PROGRAMMING & COMPUTER GRAPHICS LABORATORY

SE-COMPUTER ENGINEERING

SEMESTER-I

Subject Code:**210247**

TEACHING SCHEME
Lectures: 4Hrs/Week
Practical: 2 Hrs/Week

EXAMINATION SCHEME
Practical :25 Marks
Term Work:25 Marks

-: **Name of Faculty**:-
Prof. N. G. Bhojne
Prof. A. M. Karanjkar
Prof. P. D. Bendale
Prof. P. G. Waware

COMP
DEPT

H.O.D.
DEPT. OF COMPUTER ENGG.
Sinhgad College of Engineering
44/1, Vadgaon (BK), Sinhgad Road,
Pune-411041

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Suggested List of Laboratory Experiments/Assignments

(All assignments are compulsory)

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2	Develop a program in C++ to create a database of student's information system containing the following information: Name, Roll number, Class, Division, Date of Birth, Blood group, contact address, Telephone number, Driving license no. and other. Construct the database with suitable member functions. Make use of constructor, default constructor, copy constructor, destructor, static member functions, friend class, this pointer, inline code and dynamic memory allocation operators-new and delete as well as exception handling.	13
3	Imagine a publishing company which does marketing for book and audio cassette versions. Create a class publication that stores the title (a string) and price (type float) of publications. From this class derive two classes: book which adds a page count (type int) and tape which adds a playing time in minutes (type float). Write a program that instantiates the book and tape class, allows user to enter data and displays the data members. If an exception is caught, replace all the data member values with zero values.	23

GROUP B

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GROUP C

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6	Write C++ program using STL for sorting and searching user defined records such as personal records (Name, DOB, Telephone number etc) using vector container. **OR** Write C++ program using STL for sorting and searching user defined records such as Item records (Item code, name, cost, quantity etc) using vector container.	50
7	Write a program in C++ to use map associative container. The keys will be the names of states and the values will be the populations of the states. When the program runs, the user is prompted to type the name of a state. The program then looks in the map, using the state name as an index and returns the population of the state.	57

PART-II : COMPUTER GRAPHICS

Suggested List of Laboratory Experiments/Assignments

(All assignments are compulsory)

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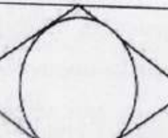
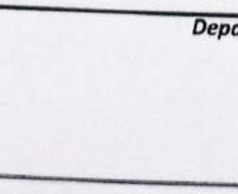
3	A) Write C++ program to draw the following pattern. Use DDA line and Bresenham's circle drawing algorithm. Apply the concept of encapsulation.  **OR** B) Write C++ program to draw the following pattern. Use DDA line and Bresenham's circle drawing algorithm. Apply the concept of encapsulation. 	72

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GROUP B

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MINI PROJECT/CASE STUDY		
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Assignment No.	1 (GROUP A)
Title	Implement a class Complex which represents the Complex Number data type. Implement the following 1. Constructor (including a default constructor which creates the complex number 0+0i). 2. Overload operator+ to add two complex numbers. 3. Overload operator* to multiply two complex numbers. 4. Overload operators << and >> to print and read Complex Numbers
Subject	Object Oriented Programming
Class	S.E. (C.E.)
Roll No.	
Date	
Signature	

Assignment No: 1

Title: Arithmetic operations on complex numbers using operator overloading

Problem Statement: Implement a class Complex which represents the Complex Number data type. Implement the following operations:

1. Constructor (including a default constructor which creates the complex number 0+0i).
2. Overloaded **operator+** to add two complex numbers.
3. Overloaded **operator*** to multiply two complex numbers.
4. **Overloaded << and >>to print and read Complex Numbers**

Prerequisites: Object Oriented Programming

Objectives: To learn the concept of constructor, default constructor, operator overloading using member function and friend function.

Theory:

Operator Overloading : It is a specific case of polymorphism where different operators have different implementations depending on their arguments. In C++ the overloading principle applies not only to functions, but to operators too. That is, of operators can be extended to work not just with built-in types but also classes. A programmer can provide his or her own operator to a class by overloading the built-in operator to perform some specific computation when the operator is used on objects of that class.

An Example of Operator Overloading

Complex a(1.2,1.3); *//this class is used to represent complex numbers*

Complex b(2.1,3); *//notice the construction taking 2 parameters for the real and imaginary part*

Complex c = a+b; *//for this to work the addition operator must be overloaded*

Arithmetic Operators

Arithmetic Operators are used to do basic arithmetic operations like addition, subtraction, multiplication, division, and modulus. The following table list the arithmetic operators used in C++

Operator	Action
+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Modulus

With C++ feature to overload operators, we can design classes able to perform operations usingstandard operators. Here is a list of all the operators that can be overloaded:

<table>
<tr><th>Over loadable operators</th></tr>
<tr><td>+ - * / = <> += -= *= /= <<>>
<<= >>= == != <= >= ++ -- % & ^ ! |
~ &= ^= |= && || %= []</td></tr>
</table>

- To overload an operator in order to use it with classes we declare *operator functions*, which are regular functions whose names are the operator keyword followed by the operator signthat we want to overload. The format is:
- type operator operator-symbol (parameters) {/*...*/ }
- The **operator** keyword declares a function specifying what *operator-symbol* means when applied to instances of a class. This gives the operator more than one meaning, or "overloads" it. The compiler distinguishes between the different meanings of an operator by examiningthe types of its operands.

Syntax:

```
return_typeclass_name :: operator op(arg_list)
{
//function body
}
```

where,

- Return type is the value returned by the specified operation
- op is the operator to be overload.
- op is proceeding by the keyword operator.
- operator op is the function name

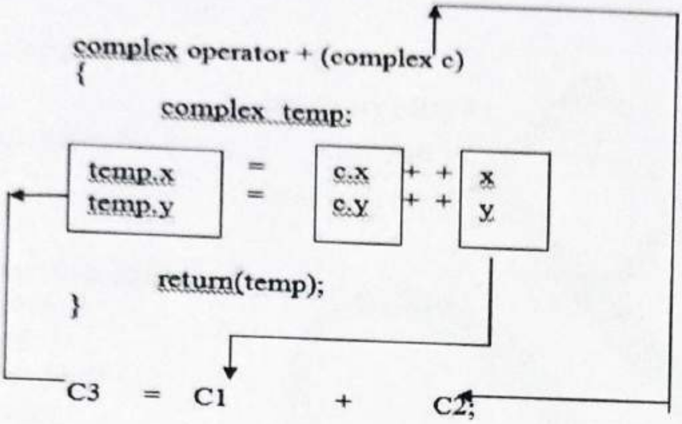
Process of the overloading has 3 steps

1. Create a class that define a data types that is used in the overloading operation
2. Declare the operator function operator op() in the public part of the class.It may be either a member function or a friend function.
3. Define the operator function to implement the required operation

e.g. Overloading Binary operators: A statement like

C = sum (A, B); // functional notation

This functional notation can be replaced by a natural looking expression



```
complex operator + (complex c)
{
    complex temp;
    temp.x  =  c.x  + +  x
    temp.y  =  c.y  + +  y
    return(temp);
}
C3 = C1 + C2;
```

Facilities:

Linux Operating Systems, G++

Algorithm:

Step 1: Start the program

Step 2: Create a class complex

Step 3: Define the default constructor.

Step 4: Declare the operator function which are going to be overloaded and display function

Step 5: Define the overloaded functions such as +, -,/,* and the display function

For Addition:

(a+bi) + (x + yi) = ((a+x)+(b+y)i)

For Multiplication:

(a+bi) * (x + yi) = (((a*x)-(b*y)) + ((a*y) + (x*b))i)

Step 6: Create objects for complex class in main() function

Step 7:Create a menu for addition, multiplication of complex numbers and display the result

Step 8: Depending upon the choice from the user the arithmetic operators will invoke the overloaded operator automatically and returns the result

Step 9: Display the result using display function

Input:

Complex numbers with real and imaginary values for two complex numbers.

Example :

Complex No 1: Real Part : 5
Imaginary part : 4
Complex No 2: Real Part : 5
Imaginary part : 4

Output:

```
Default constructor value=0+0i
Enter the 1st number
Enter the real part2
Enter the imaginary part4
Enter the 2nd number
Enter the real part4
Enter the imaginary part8
The first number is 2+4i
The second number is 4+8i
The addition is 6+12i
  The multiplication is -24+32i
```

Conclusion:

Hence, we have studied concept of operator overloading.

Questions:

1. What is operator overloading?
2. What are the rules for overloading the operators?
3. State clearly which operators are overloaded and which operator are not overloaded?
4. State the need for overloading the operators.
5. Explain how the operators are overloaded using the friend function.
6. What is the difference between "overloading" and "overriding"?
7. What is operator function? Describe the syntax?
8. When is Friend function compulsory? Give an example?