Bapatla Engineering College

(Autonomous)

(Sponsored by Bapatla Education Society)

GBC Rd, Mahatmajipuram, BAPATLA, Andhra Pradesh - 522102

(Approved by AICTE, New Delhi & Affiliated to Acharya Nagarjuna University, Guntur)

www.becbapatla.ac.in

LABORATORY MANUAL

Department of Physics

Name of the Laboratory: Semiconductor Physics Lab

Course Code: 26CSL101 / 26CML103 / 26CBL103 / 26DSL103 / 26ECL201 / 26ITL202

NAME OF THE STUDENT			
SECTION		REGD.NO	



Vision of the Department

* To inculcate the proper knowledge of fundamentals of physics, students are enabling to take up practical and scientific skills in their professional courses. It will promote research in interdisciplinary areas in order to keep the stakeholders updated with necessary information.

* To integrate Physics and Engineering Courses.

Mission of the Department

* The mission of the department of Physics is to provide high quality education through teaching and learning experiences to our first year students and to provide students with basic skills in solving problems in scientific and technical area of interest

* To start the courses in the emerging areas (as per UGC guide lines) like Nanotechnology, Computational Physics, etc. so as to develop it as an advanced center Material Science Engineering.

Program Outcomes:

Engineering graduates will be able to:

PO1. **Engineering knowledge:** Apply knowledge of mathematics, science, computing, and engineering fundamentals to complex engineering problems.

PO2. **Problem analysis:** Identify, formulate, and analyze complex engineering problems to reach substantiated conclusions.

PO3. **Design/development of solutions:** Design solutions for complex problems and systems while considering public health, safety, and environmental factors.

PO4. **Conduct investigations of complex problems:** Use research-based knowledge and methods, including experiment design and data analysis, to provide valid conclusions.

PO5. **Modern tool usage:** Apply appropriate modern engineering and IT tools and techniques to complex activities.

PO6. The Engineer and the World – Evaluate societal, legal, and environmental sustainability impacts of engineering solutions

PO7. Ethics – Apply professional ethics, responsibilities, and legal principles.

PO8. Individual and Collaborative Teamwork – Function effectively as an individual or as a member/leader in diverse, multidisciplinary teams.

PO9. Communication – Communicate effectively on complex engineering activities with the engineering community and society.

PO10. Project Management and Finance – Demonstrate knowledge of engineering and management principles to manage projects and economic decisions.

PO11: Life-Long Learning – Recognize the need for and adapt to independent, life-long learning in the context of technological change

Semiconductor Physics Lab
I B.Tech
Common to CS,CM,CB,DS,EC,IT

Code: 26CSL101 / 26CML103 / 26CBL103 / 26DSL103 / 26ECL201 / 26ITL202

Lectures	0	Tutorial	0	Practical	2	Credits	1
Continuous Internal Evaluation			40	Semester End Examination			60

Pre-Requisite: None.

Course Outcomes: At the end of this course, Students will be able to

CO1	Acknowledge the important aspects of earth magnetic field, realize the use of Maxwell's equations in various magnetic applications
CO2	Realization of material properties and parameters
CO3	Get hands-on experience in various Opto-electronic devices like CRO, Solar Cell, Photo Cell and their applications
CO4	To apply the phenomenon of interference and LASER principles to find radius of curvature and wavelength respectively by various methods

Mapping of Course Outcomes with Program Outcomes

CO	POs											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	3	3	2	2	-	-	-	-	2	-	-	-
CO2	3	3	2	2	-	-	-	-	2	2	-	-
CO3	3	3	2	2	2	-	-	-	2	-	-	-
CO4	3	2	-	-	-	-	3	-	-	-	-	2

Semiconductor Physics Lab
I B.Tech
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Code: **26CSL101 / 26CML103 / 26CBL103 / 26DSL103 / 26ECL201 / 26ITL202**

LIST OF EXPERIMENTS

1. Determination of acceleration due to gravity at a place using compound pendulum.
2. To study the variation of intensity of magnetic field along the axis of a circular coil using Stewart-Gee's apparatus.
3. To draw the characteristic curves of P-N Junction diode.
4. Determination of radius of curvature of a Plano convex lens by forming Newton's rings.
5. Determination of wavelengths of mercury spectrum using grating normal incidence method.
6. To draw the characteristic curves of Zener diode.
7. To draw the resonant characteristic curves of L.C.R. series circuit and calculate the Resonant frequency.
8. To draw the characteristic curves of a photocell and calculate the maximum velocity of electron.
9. Verify the laws of transverse vibration of stretched string using Sonometer.
10. Determination of rigidity modulus of the given material of the wire using Torsional pendulum.
11. To draw the load characteristic curves of a solar cell.
12. Determination of Hall coefficient of a semiconductor.
13. Determination of voltage and frequency of an A.C. signal using C.R.O.
14. Determination of Forbidden energy gap of Si &Ge.
15. Determination of wavelength of laser source using Diode laser.
16. Characteristic of a Photo diode.

Any three experiments are virtual

Note: A minimum of **ten experiments** to be done and recorded

Text Books :	Engineering Physics laboratory Manual by P.Sreenivasarao & K.Muralidhar, Himalaya Publications.

1. COMPOUND PENDULUM

AIM : To determine acceleration due to gravity (g)at a place using compound pendulum.

APPARATUS: Compound pendulum, knife edges, telescope, stop watch, meter scale.

DEFINATION OF 'g': When a body is left to free fall, then it acquires a constant acceleration and move towards earth, due to earth's gravitation. Now the constant acceleration acquired by that freely falling body is called acceleration due to gravity.

FORMULA: Time period of oscillation of a physical pendulum or compound pendulum is given by

$$T = 2\pi\sqrt{\frac{K^2+D^2}{gD}}\ Sec$$

Compare the above formula with time period of oscillation of a simple pendulum. i.e.

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

Here $\mathbf{L} = \sqrt{\frac{K^2+D^2}{D}}$ is called length of equivalent simple pendulum. K is radius of gyration; 'D' is distance of the point of suspension from center of gravity. The value of " L " is estimated from a graph drawn between distance of point of suspension (l) verses time period of oscillation (T)

From the above formula acceleration due to gravity is given by $\mathbf{g = 4\,\pi^2\left(\frac{L}{T^2}\right)\ cm/s^2}$

THEORY:

In lower classes you might be familiar with simple pendulum experiment for the determination of acceleration due to gravity, hence, before doing this experiment one has to know the difference between simple pendulum, and compound pendulum experiment, both of them were meant for determination of 'g' value. They are

1. Simple pendulum is an ideal case, because it requires a point mass object
2. It requires torsion less string.

The above-mentioned two conditions are practically not possible, hence it is only a mathematical ideal case, and whereas compound pendulum is a physical pendulum. A rigid body of any shape which is free to oscillate without any friction on a vertical plane is called compound pendulum. It swings harmonically back and forth about a vertical z-axis (Passing through point "O" as shown in Fig), when compound pendulum is displaced from its equilibrium position by an angle $\boldsymbol{\theta}$. In the equilibrium position, the center of gravity of the body is vertically below at OG. Let the mass of the body is m, In this experiment you are going

to measure the acceleration due to gravity, g by observing the motion of a compound pendulum. Let us consider a compound pendulum shown in figure 1.

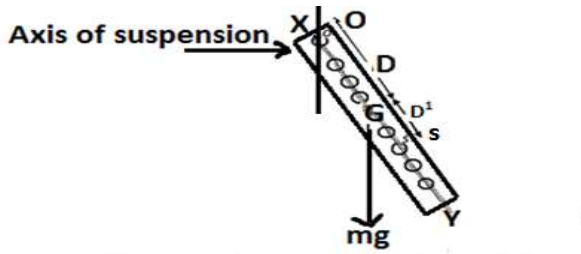
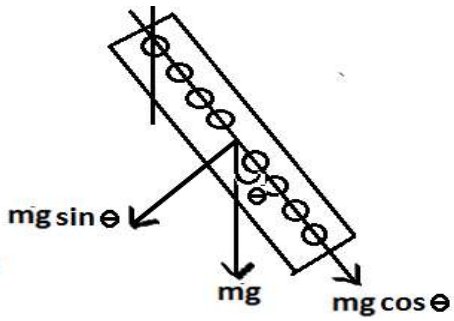


Fig 1. oscillation of a compound pendulum



Pull the compound pendulum through an angle $\boldsymbol{\theta}$ and release it, then it makes angular oscillations due to torque acting on it, given by

$$\vec{\tau} = \vec{r}\, X\, \vec{F}$$

$$\vec{\tau} = \overrightarrow{OG} X \overrightarrow{mg}\, sin\theta$$

$$\vec{\tau} = -mgDsin\theta ----(1)$$

Here –ve sign is because of force and displacement is opposite to each other.

For small amplitudes $Sin\theta \approx \theta$

Now expression (1) becomes $\vec{\tau} = -mgD\theta$

We know that torque $\vec{\tau} = (Moment\ of\ inertia\ (I))[Angular\ accelaration\ (\alpha)]$

$$\tau = I\frac{d^2\theta}{dt^2}$$

$$=> I\frac{d^2\theta}{dt^2} = -mgD\theta$$

$$\frac{d^2\theta}{dt^2} + \left(\frac{mgD}{I}\right)\theta = 0 ----(2)$$

Here I is the moment of inertia of pendulum, about an axis passing through point "O".

Equation (2) represents simple harmonic equation of the form, i.e.

$$\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$$

Here $\omega$is angular frequency of simple pendulum. From comparison with Eq (2), we can write

$$\omega = \sqrt{\frac{mgD}{I}}$$

$$=>\omega = \frac{2\pi}{T} = \sqrt{\frac{mgD}{I}}$$

$$=>T = 2\pi\sqrt{\frac{I}{mgD}} ----(3)$$

According to parallel axes theorem, the rotational moment of inertia, about any axis parallel to the one passing the center of gravity is given by

$$I = I_G + mD^2 - - - (4)$$

We know that moment of inertia about an axis passing through center of gravity "G", given by

$$I_G = mk^2$$

Here "K" is radius of gyration of the body about an axis passing through "G".

Thus $T = 2\pi\sqrt{\frac{mk^2+mD^2}{mgD}} = 2\pi\sqrt{\frac{D+\frac{k^2}{D}}{g}} - - - - - (5)$

Comparing expression (5) with expression for time period of simple pendulum i.e.

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

This suggests that $L = D + \frac{k^2}{D} = D + D^1 - - - -(6)(\ let\ D^1 = \frac{k^2}{D})$

The term **"L"** is called length of ***"equivalent simple pendulum".***

This is because simple pendulum of length "L" is having a time period, same as that of time period of compound pendulum. Also it seems that all the mass of the body were concentrated at point **"S",** along "OG" produced such that $OS = D + \frac{k^2}{D} = D + D^1$

The point "S" is called center of oscillation. In analogy with simple pendulum, we may suppose that, the entire mass is concentrated at that point.

From expression (6), the extra distance $D^1 = \frac{k^2}{D}$ is below the center of gravity "G", at a point "S", and is shown in Figure (1).

From expression (6) we can write

$$D^2 - LD + K^2 = 0$$

The above equation is a quadratic equation in "D" and it's two roots are given by

$$D_1 = \frac{L + \sqrt{L^2 - 4K^2}}{2}\ and\ D_2 = \frac{L - \sqrt{L^2 - 4K^2}}{2}$$

That is for each half of pendulum, there are two different points of oscillation ***(do not get confusion with center of oscillation)*** i.e. which are at $D_1 and\ D_2$ distance away from center of gravity **"G"**, for which the value of **"L"** is same. Since **"L"** is same for $D_1 and\ D_2$, then, the time period is also same. When we perform this experiment on both sides of center of gravity "G" we have a total of 4 points (2 points on one side) having same time period "T", as shown in Figure 2. The points $D\ and\ D^1$ are clearly shown in Graph.

It is sometimes convenient to specify, the location of axis of suspension or point of oscillation "O", by the distance from end of the bar, instead of distance "D" from center of gravity. By

varying the position of axis of suspension, measure the corresponding time period, and tabulate all the observation in the following

TABULAR FORM FOR THE DETERMINATION OF TIME PERIOD

S.No	Distance of knife edge from one end of the bar."D"	Time taken for 20 oscillations			Time period T=t/20 Sec
		Trail 1	Trail 2	Mean time (t) sec	
1					

TABULAR FORM FOR THE DETERMINATION OF EQUIVALENT LENGTH OF SIMPLE PENDULUM

S.No	Time period "T"	T^2	AC	BD	$L = \frac{AC + BD}{2}$	$\frac{L}{T^2} = Constant$
1						

Graph:

1. Draw a graph between "D" values on x-axis and corresponding "T" values on Y- axis, then we get the following nature of graph.(Fig 1). Draw a straight line, at one particular "T" value, then it intersect the graph at four points and mark them as A,B,C,& D

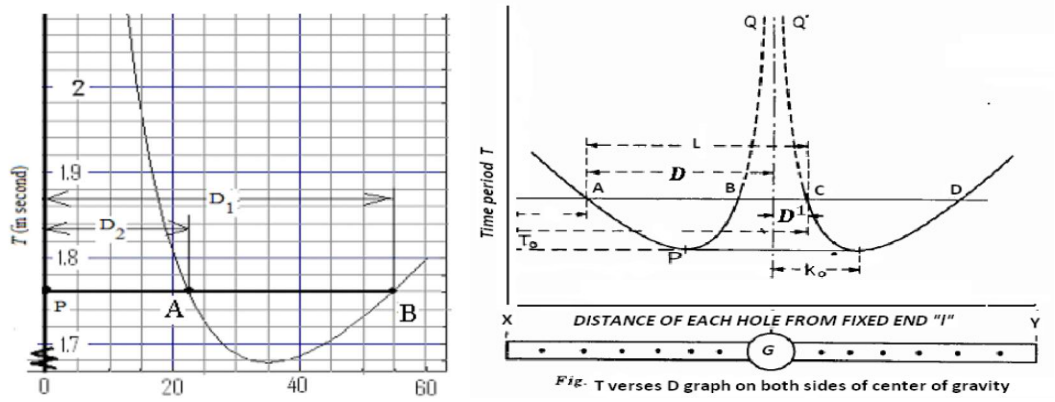


Fig. T verses D graph on both sides of center of gravity

Fig. "T" verses "D" graph for each half of the compound pendulum

GRAPH 2.

A graph is drawn between "L" values on X-axis and corresponding "T^2" values from table 2, on Y-axis, and then the nature of graph is as shown in Fig4

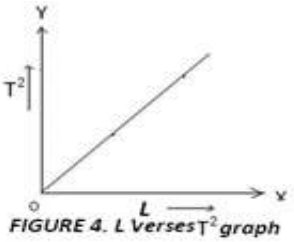


FIGURE 4. L Verses T^2 graph

NOTE: We can also find "L" value from Fig 2 as sum of $D_1 and\ D_2$. We can show it as sum of expression for $D_1 \& D_2$.

i.e. **$L=D_1 + D_2 = PA + PB$ (According to Fig1)**

$$D_1 + D_2 = \frac{L + \sqrt{L^2 - 4K^2} + L - \sqrt{L^2 - 4K^2}}{2} = \frac{2L}{2} = L$$

PRECAUTIONS: 1. Angular displacement of the pendulum should be confined to below 10^o
2. Pendulum should oscillate only in vertical plane, without wobbling.
3. Knife edge should rest on horizontal surface only.

RESULT: Acceleration due to gravity using compound pendulum was found to be _____

VIVA-VOCE QUESTIONS

1.Define acceleration due to gravity.

2.What is the difference between two experiments i.e Simple pendulum & Compound pendulum for the measurement of acceleration due to gravity

3.What do you mean by equivalent length of simple pendulum.

4.How acceleration due to gravity varies with latitude & longitude position.

5.Why don't you observe this experiment from first hole to last hole continuously, without reversing the pendulum.

6. What is the time period of oscillation at center of gravity position

7. Why pendulum is restricted to oscillate in smaller angular amplitude.

8. Why you are using telescope for the measurement of time period of oscillation

2. TORSIONAL PENDULUM

AIM: To determine the rigidity modulus of the material of the wire by the method of oscillations.

APPARATUS: Circular disc with chuck, given wire (suspension wire), stop clock, two equal cylindrical masses, screw gauge, vernier calipers and meter scale.

FORMULA: Rigidity modulus of given wire using torsional pendulum is given by

$$\eta = \frac{16\pi ml}{a^4}\left(\frac{d_2^2 - d_1^2}{T_2^2 - T_1^2}\right) \; dyne/cm^2$$

Here m=mass of each cylinder, gm.

l = length of the wire, cm

a = radius of the wire, cm

$d_1 \& d_2$ *are distance of the cylinder center from chuck nut center*

$T_1 \& T_2$ *are time period of oscillation corresponding to distance* $d_1 \& d_2$

THEORY:

Torsional pendulum consists of a metal wire clamped to a rigid support at one end and carries a heavy circular disc at the other end. When the suspension wire of the disc is slightly twisted, the disc at the bottom of the wire executes torsional oscillations such that the angular acceleration of the disc is directly proportional to its angular displacement and the oscillations are simple harmonic.

PROCEDURE:

One end of a long, uniform wire whose rigidity modulus is to be determined is clamped by a vertical chuck. To the lower end, a heavy uniform circular disc is attached by another chuck. The length of the suspension $\boldsymbol{l}$ (from top portion of chuck to the clamp) is fixed to a particular value (say 60 cm or 70 cm). Keep the two cylindrical masses at equal distance from chuck nut and note down this distance. At this position, the suspended disc is slightly twisted so that it executes torsional oscillations. The first few oscillations are omitted. By using the pointer, (a mark made in the disc) the time taken for l0 complete oscillations are noted. Two trials are taken. Then the mean time period T (time for one oscillation) is found. The above procedure is repeated, by keeping the cylinders at various equal distances from chuck nut. The diameter of the wire is accurately measured at various places along its length with screw gauge. From this, the radius of the wire is calculated. Tabulate all the observations in the various table forms, shown below.

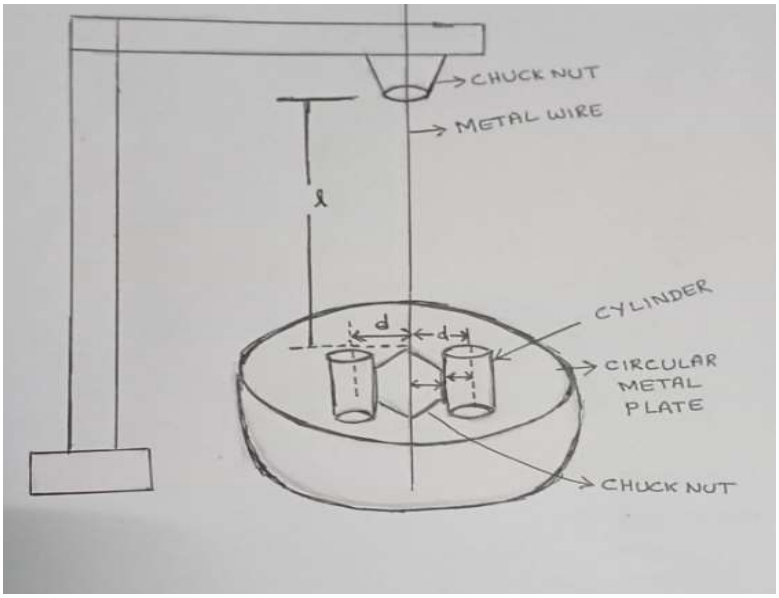


TABLE -1 FOR THE DETERMINATION OF RADIUS OF CYLINDER USING VERNIER CALIPERS.

S.No	M.S.R "a" cm	VC	VCxLC "b" cm	Radius=$\frac{a+b}{2}$ cm

TABLE-2 FOR THE DETERMINATION OF RADIUS OF CHUCK NUT USING VERNIER CALIPERS

S.No	M.S.R "a" cm	VC	VCxLC "b" cm	Radius=$\frac{a+b}{2}$ cm

TABLE-3 FORTHE DETERMINATION OF RADIUS OF WIRE USING SCREW GAUGE

Screw gauge error: ___+ve/___-Ve Correction ___-ve/___+ve LC=0.001cm

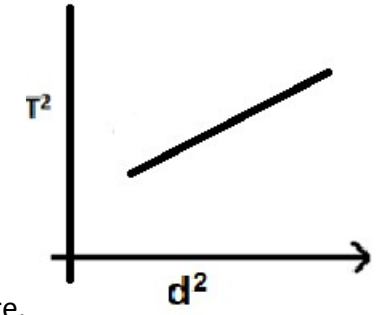
S.No	P.S.R "a" cm	H.S.R		b=nxLC cm	Diameter "a+b" Cm	Radius=$\frac{a+b}{2}$ Cm
		Observed	Corrected "n"			

TABLE -4 FOR THE DETERMINATION OF TIME PERIOD OF OSCILLATION

Length of the wire $l = - - - - cm$

S.No	Distance of the cylinder center from chuck nut center (d) cm	Time taken for 10 oscillations			Time period(T)=t/10 sec	d^2 Cm^2	T^2 Sec^2
		Trail-1	Trail-2	Mean(t)			

GRAPH: A graph is drawn between d^2 values on X-axis and T^2 values on Y-axis, then the nature of the graph is as shown in Figure.



PRECAUTIONS:

l. The suspension wire should be well clamped, thin long and free from kinks.

2. The period of oscillations should be measured accurately since they occur in second power in the formula.

3. Radius of the wire should be measured very carefully since it occurs in fourth power.

Applications:

1. This method is used to find the moment of inertia of any irregular materials and the elastic limit of the given wire.

2. By knowing the moment of inertia, the time period of oscillations can be found.

RESULT: Rigidity modulus of the wire is given by _____dyne/cm^2

VIVA-VOCE QUESTIONS

1. Define rigidity modulus of a rigid body

2. Define elastic modulus

3. How you can understand a material possessing high rigidity modulus value when compared with another material having low value of rigidity modulus

4. Suppose you have two steel wires of different diameters, which of them possess more rigidity modulus or both of them have same value of rigidity modulus. How do you justify your answer.

5. What do you mean by torsional oscillations

3.NEWTON RINGS

AIM : To determine the radius of curvature of given plano - convex lens by forming Newton rings.

APPARATUS: Plano – convex lens, optically plane glass plate, Plane glass plate inclined at 45^0, sodium vapour lamp, travelling microscope, reading lens, black sheet.

PRINCIPLE: This experiment is based on the principle of interference.

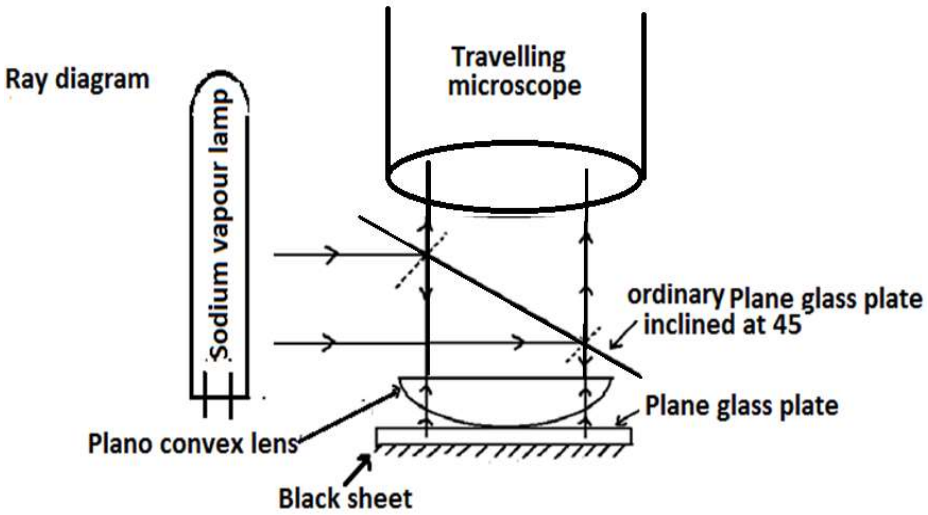
NATURE OF INTERFERENCE PATTERN: In this experiment all the fringes are circular in shape, with central dark fringe (in reflected system only). The fringes are circular due to locus all the points which are having, constant air film thickness is lie along the circumference of a circle.

FORMULA: The expression for radius of curvature of a given plano-convex lens, in Newton rings is given by

$$R = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} cm$$

Here D_m & D_n are the diameters of m^{th} & n^{th} ring respectively.

λ= Wavelength of light source used. (Use λ=5890 A^o)



THEORY :

When light from sodium vapour lamp is allowed to fall directly on to a ordinary plane glass plate inclined at 45^0 , it is reflected at 45^0 (according to laws reflection and refraction) and fall normally (i.e angle of incidence ' i ' = 0^0) onto the system of plane glass plate and plano-convex lens. When convex surface of plano- convex lens is placed on plane glass plate, it rests at one point, as shown in fig. The air film thickness between convex surface and plane glass plate is gradually increasing from the point of contact (where thickness of the film is zero), called wedge shaped film. The light rays which fall normally onto the system undergo first reflection at plano - convex lens surface, and second reflection from plane glass plate. Since both these light rays are derived from same source, they possess same wavelength and have a constant phase difference equal to thickness of the air film at that place. These light rays interfere in the field of view of travelling microscope, producing interference fringes as concentric circles of alternate bright and dark. This is because, locus of all the points, which are reflected at same air film thickness lie along the circumference of a circle.

PROCEDURE:-

1) Glass plate and lenses are thoroughly cleaned.

2) First, we must distinguish between a **plane glass plate** and a **plano-convex lens**. This can be done by shaking the lens while viewing an object through it.
(i) If the image of the object appears to move (shake) when the lens is shaken, then the object is a **plano-convex lens**.
(ii) If the image of the object does not move when the glass is shaken, then it is a **plane glass plate**.

Now keep the plano-convex lens on plane glass plate and gently rotate. If it stops rotating immediately, then it means that the plane side of plano-convex lens is rested on the plane glass plate. If it rotates for some time, then it means the convex side of plano-convex lens is rest on plane glass plate.

3) The glass plate in the Newton's rings apparatus is set such that it makes an angle of 45^0 with the direction of incident light coming from the source. It is the necessary condition for the well illumination of combination and to allow light rays to fall normally on to that system.
4) The microscope is moved in a vertical direction till the rings are seen distinctly.

5) The center of the fringes is brought symmetrically below the cross wires by adjusting the position of the lens and the microscope.

6) The microscope is moved in horizontal direction to one side of the fringes such that one of the cross wires becomes tangential to the 18th ring. Note down the main and vernier scale readings.

7) Move the microscope and make the cross wire tangential to the 16th, 14th up to 8th ring and on the other side up to 18th ring. Note down the readings.

8) The radius of curvature of the curved surface of the plano-convex lens is determined using spherometer. Place the lens with its curved surface upwards on the glass plate. Take the spherometer reading when it just touches the surface. Remove the lens. Take the reading on the plane surface.

9) Place the spherometer on the notebook and gently press to obtain the impression of the three legs of the spherometer. Join the three points and determine the mean distance between the legs.

Radius of curvature " R" of plano-convex surface is given by

$$R = \frac{l^2}{6h} + \frac{h}{2} cm$$

where l = distance between two legs of the spherometer, h = thickness of the lens at the centre

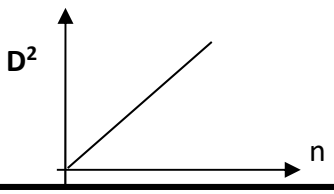
TABLULAR FORM FOR THE DETERMINATION OF DIAMETER OF A RING

S.No	Ring number " n "	Readings of travelling microscope						Diameter of the ring D = $R_L \sim R_R$ cm	D^2 Cm^2
		Left			Right				
		M.S.R " a "	VC x LC " b"	Total reading R_L= a+b	M.S.R " a "	VC x LC " b"	Total reading R_R= a+b		

GRAPH:

Plot a graph by taking ring number on X- axis and corresponding square of the diameter of the ring on Y- axis, we get a graph as a straight line passing through origin as shown in Fig. below.

" R " value can also be found from the graph, by taking the slope of the straight line



PRECAUTIONS:-

1) Glass plates and lens should be cleaned thoroughly.
2) In order to avoid any error due to back-lash of the screw in the travelling microscope, the micrometer screw should be moved only in one direction for the measurement of diameter of rings
3) Crosswire should be focused on a bright ring tangentially.
4) Do the calculation in cgs units only.

RESULT: The radius of curvature of given plano - convex lens was found to be _____ cm

VIVA-VOCE QUESTIONS

1. By which wave phenomena Newton rings are formed.

2. Why is ordinary glass plate kept at 45^0 for formation of fringes.

3. Why do we keep a black sheet below the bottom glass plate, can we use any colour sheet in place of black sheet.

4. Why are fringes in circular shape?

5. If you observe irregular shaped circular fringes, what you can say from that One.

6. What we can measure from Newton rings, other than radius of curvature.

7. If sodium vapour lamp is replaced by white light source, what you observe in fringe pattern.

8. Define radius of curvature of a lens.

4.DETERMINATION OF WAVELENGTH OF LASER BY DIFFRACTION GRATING

AIM: To determine wavelength of LASER source by using plane transmission grating.

APPARATUS: Diode LASER, power supply, plane transmission diffraction grating, scale, screen, graph paper.

FORMULA: The condition for nth order diffraction principle maxima is given by

$$(e+d)sin\theta = n\lambda - - - - - (1)$$

Here (e+d) is width of each slit or grating element, "n" is order of diffraction.

From Fig 2 $$Sin\theta_n = \frac{x_n}{\sqrt{x_n^2+D^2}} - - - (2),$$

where x_n *is the distance of* n^{th} *order from zeroth order*

The expression for wavelength of LASER source from the above expression is given by

$$\lambda = \left(\frac{e+d}{n}\right)\left[\frac{x_n}{\sqrt{x_n^2+D^2}}\right] \text{Å}$$

"D" is distance between grating and screen

THEORY:

We know that grating refers to a set of parallel lines with equal spacing. When such arrangement was made on a plane glass plate, then it is called optical grating. Each line on the slit is acting as an obstacle to the light propagation and light undergoes diffraction. The plane transmission diffraction grating used in the laboratory consists of 15,000 lines per inch. Width of each opaque part is 'd' and width of each transparent part is 'e'. 'e+d' is called grating element or width of each slit. When LASER light falls on grating surface it is diffracted, and diffraction spots are observed on either side of central maxima as shown in Fig. The distance of each order spot from central bright spot must be equal. At one distance between grating and screen distance of each 'D' , note down the distance of each spot, on both sides of central maxima. Repeat the same for other distances also.

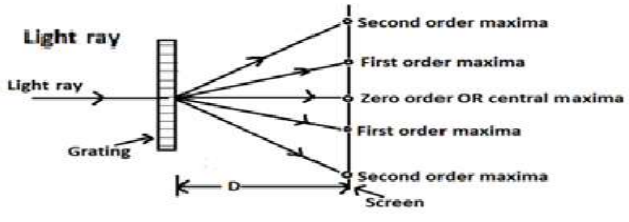


FIGURE-1

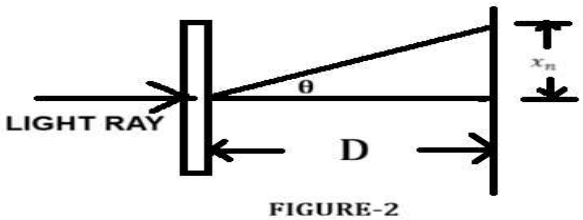


FIGURE-2

TABLE FORM

S.No	Distance between screen & grating (D)	Distance of n^{th} order from central maxima			$\lambda = \left(\frac{e+d}{n}\right)\left[\frac{x_n}{\sqrt{x_n^2+D^2}}\right]$ Å
		Left Cm	Right Cm	Mean(X_n) Cm	

PRECAUTIONS

1. Clean the grating surface with soft cloth and do not touch the surface with fingers till the experiment is over.

2. Mark spots of various orders on graph paper with pencil at the center of that spot.

3. Do not see the LASER light with naked eye, because it causes loss of sensation of vision

RESULT: The wavelength of laser light using plane diffraction grating was found to be_____

VIVA-VOCE QUESTIONS

1. **By which wave phenomena, LASER light is split into various points on Screen, after passing through grating**

2. **Define diffraction of light and the condition for light to undergo diffraction.**

3. **What do you mean by grating.**

4. **Can you observe diffraction of x-rays, through the diffraction grating used in Laboratory, justify your answer.**

5. **What is acronym of LASER.**

6. **What is the difference between ordinary & LASER light**

5. SOLAR CELL

AIM: To study the characteristics of a photo voltaic cell (Solar cell) and to find Fill factor.

APPARATUS: Solar cell, d.c milli voltmeter, d.c micro ammeter, variable resistance box, 100W Lamp, connecting wires.

PRINCIPLE: This experiment is based on the principle of photo voltaic effect. i.e. When light energy falls on to a open circuited P-N junction, electron- hole pairs are created, and they were separated by junction electric field. These separated charges accumulated on P and N regions and leading to create potential difference across the ends, called Photo – voltaic effect.

FORMULA: Fill factor of a solar cell is given by

$$\text{Fill Factor} = \frac{P_{Max}}{I_{sc}\,X\,V_{oc}} = \frac{V_m\ X\ I_m}{I_{sc}\,X\,V_{oc}}$$

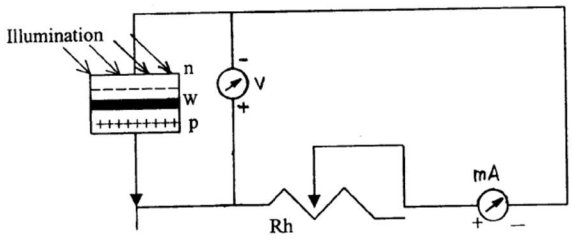
Where I_{sc} = short circuit current (when resistance in the circuit is zero i.e. R=0)

V_{oc} = open circuit voltage (when resistance in the circuit is infinite i.e. R= ∞)

$I_{sc}\,X\,V_{oc}$= is the ideal power or dummy power output, and $V_m\ X\ I_m$ is actual maximum obtainable power

The fill factor is defined as the ratio of the actual maximum obtainable power, to the product of the open circuit voltage and short circuit current. This is a key parameter in evaluating the performance of solar cells. Typical commercial solar cells have a fill factor > 0.70. Grade B cells have a fill factor usually between 0.4 to 0.7. The fill factor is, besides efficiency, one of the most significant parameters for the energy yield of a photovoltaic Cells with a high fill factor have a low equivalent series resistance and a high equivalent shunt resistance, so less of the current produced by light is dissipated in internal losses.

CIRCUIT DIAMGRAM:



THEORY:

A solar cell (also called photovoltaic cell or photoelectric cell) is a solid-state electrical device that converts the energy of light directly into electricity by the photovoltaic effect. Assemblies of solar cells are used to make solar modules which are used to capture energy from sunlight.

When multiple modules are assembled, the resulting integrated group of modules all oriented in one plane is referred to in the solar industry as a solar panel. Electric energy generated from solar modules, referred to as solar power, is an example of solar energy. A solar cell is basically a P-N Junction semiconductor diode, usually made from silicon. The thickness of P-region and N-region are kept very small so that electrons and holes generated near the surface can diffuse across the junction before recombination takes place. A heavy doping of p– and n- regions is recommended to obtain a large photo voltage. When light falls on a pn-junction diode, photons collide with valence electrons and impart sufficient energy enabling them to leave their parent atom. Thus electron-hole pairs are generated in both the p- and n-sides of the junction. These electrons and holes reach the depletion region by diffusion and are then separated by the strong barrier field existing there. However, the minority carrier electrons in the p-side slide down the potential barrier to reach the n-side, and holes on the n-side move to the p-side. Their flow continues to the minority current, which is directly proportional to the illumination, and depends on the surface area being exposed to light. The accumulation of electrons and holes on the two sides of the junction gives rise to an open circuited voltage V_{oc} , which is a function of illumination. The open circuit voltage for a silicon solar cell is typically 0.6 volt and short circuit current is about 40ma/cm^2.

EXPERIMENTAL PROCEDURE

1.Keep the solar cell in the sunlight for 15 to 20 minutes.

2. Adjust the rheostat position for resistance so that the voltmeter reads zero. This is the short circuit connection. Note down the value of the current as short circuited current, Isc. Disconnect the rheostat from circuit, then voltmeter shows maximum reading, note down the value of voltage as open circuit voltage (V_{oc})

3. Increase the resistance by varying the rheostat slowly and note down the readings of current and voltage till a maximum voltage is read. Ensure to take at least 15–20 readings in this region.

4. Repeat the experiment for another intensity of the illumination source.

5. Tabulate all readings in Table 1. Calculate the power using the relation, P = V x I.

6. Plot I vs. V with voltage V on x-axis and current I on the Y- axis

7. Identify the maximum power point Pm on graph, and project two straight lines on X and Y-axis to identify V_{oc} & I_{sc}, respectively

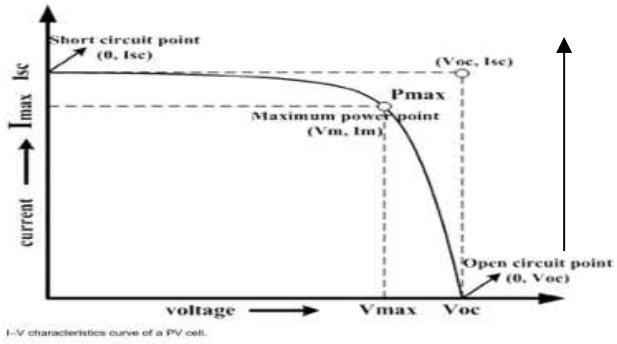
8. To see the performance of the cell calculate fill factor (FT) of the cell, which can be expressed by the formula, FF = [P_{Max}/I_{sc} x V_{oc}].

TABLE FORM FOR MEASUREMENT OF POWER

S.No	Resistance in ohms (R)	*Reading of voltmeter & ammeter*		Power =IxV watt *mW*
		Voltmeter mV	Ammeter mA	

GRAPH:

Draw a graph by taking voltage values on X-axis and corresponding current values on Y-axis, we get the following nature, as shown in Fig. Also draw two straight lines at V_{oc} and I_{sc}. The area spanned by I_{sc} x V_{oc} is the dummy power or ideal power produced from the circuit.



I–V characteristics curve of a PV cell.

PRECAUTIONS:

1. Expose the solar cell to sunlight for few minutes, for attaining stable values of current and voltage
2. Resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

RESULT: The characteristic curve for solar cell was drawn and fill factor was found to be_____

VIVA-VOCE QUESTIONS

1. What is the working principle of a solar cell.

2. Define photovoltaic effect

3. How do you define efficiency of solar cell.

4. What is purpose of silver threads on solar cells.

5. What are the various applications of solar cells.

6.FIELD ALONG THE AXIS OF A CURRENT CARRYING CIRCULAR COIL

AIM : To determine the magnetic field along the axis of a current carrying circular coil, using Stewart-Gees apparatus.

APPARATUS: Stewart-Gees apparatus, D.C. Power supply, magnetometer, commutator, rheostat, ammeter.

Working formula: The magnitude of field B along with the axis of a coil is given by

$$B = \frac{\mu_0 n i a^2}{2(x^2 + a^2)^{3/2}} \; Tesla$$

Where n = number of turns in the coil.

a = radius of the coil (Cm)

i = current in ampere flowing in the coil (Amp)

x = distance of the point from the centre of the coil. (Cm)

μ_0 = permeability of free space ($\mu_0 = 4\pi \times 10^{-7}$ H/m)

In this experiment, the coil is oriented such that, the plane of the coil is along the magnetic meridian. This can be achieved by arranging the plane of the coil parallel to magnetic needle in the magnetometer. When there was no current through the coil, needle in the magnetometer rests along geographic north and south direction (neglecting angle of declination), due to earth's magnetic field. When current passes through the circular coil, magnetic field is produced along the axis of coil i.e along geographic east and west directions. Now the needle in the magnetometer is under the influence of two magnetic fields, (one is earth's magnetic field acting along north to south & the other is magnetic field produced along east-west direction due to current carrying coil.) acting perpendicular to one another. Due to the influence of above said two fields, needle in the magnetometer is deflected to an angle $\theta$with respect to earth's magnetic field as shown in Fig shown below. According to tangent law, magnetic field along the axis of circular coil is given by $B = B_E Tan\theta$ Usually B_E horizontal component of earth's magnetic field (when neglecting angle of declination).

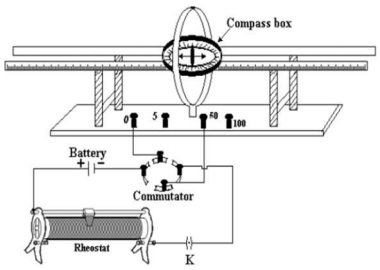
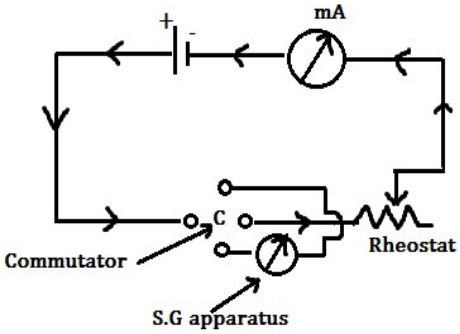


Fig. 1



CIRCUIT DIAGRAM

DESCRIPTION:

The apparatus consists of a circular coil mounted perpendicular to the base as shown in fig. A sliding compass box is mounted on aluminum rails graded with a scale on the rails, so that the

compass is always sliding on the axis of the coil, and distance from the center of the coil can be measured.

PROCEDURE: -

1. Place the magnetometer compass box on the sliding bench so that its magnetic needle is at the centre of the coil. By rotating the whole apparatus in the horizontal plane, set the coil in the magnetic meridian roughly. In this case the coil, needle and its image all lie in the same vertical plane. Rotate the compass box till the pointer ends read 0 – 0 on the circular scale.

2. To set the coil exactly in the magnetic meridian set up the electrical connections as shown in Fig. Send the current in one direction with the help of commutator and note down the deflection of the needle. Now reverse the direction of the current and again note down the deflection. If the deflections are equal, then the coil is in magnetic meridian. Otherwise turn the apparatus a little, adjust pointer ends to read 0 – 0 till these deflections become equal.

3. Using rheostat Rh adjust the current such that the deflection is between 50^0 – 60^0 degrees is produced in the compass needle placed at the centre of the coil. Read both the ends of the pointer. Reverse the direction of the current and again read both the ends of the mean deflection at x =0.

4. Now shift the magnetic compass moved through 5 cm each time along the axis of the coil and for each position note down the mean deflection. Continue the process till the compass box reaches the end of the bench.

5. Repeat the measurements exactly in the same manner on the other side of the coil.

6* Keep it mind that same current should flow at all observations. If there is any variation in current due to fluctuation, adjust the rheostat position to get that same value of current.

TABLE FORM FOR THE DETERMINATION OF 'B' VALUES.

S.No	Distance of each point from center of the circular coil (cm) "x"	Deflections in magnetometer												
		East side of the coil (degrees)					West side of the coil (degrees)							
		Direct		Reverse		θ_E=Average of θ_1 to θ_4	Direct		Reverse		θ_W=Average of θ_5 to θ_8	θ=(Average of θ_E to θ_W) (deg)	Tan θ	B = B_H Tan θ Tesla	$B = \frac{\mu_0 n i a^2}{2(x^2+a^2)^{3/2}} Tesla$
		θ_1	θ_2	θ_3	θ_4		θ_5	θ_6	θ_7	θ_8					

GRAPH: Plot graph taking "x" along X-axis, and Tanθ along Y- axis, and then we get a bell shaped graph as shown in Fig. below. The nature of the graph is symmetrical about Y- axis.

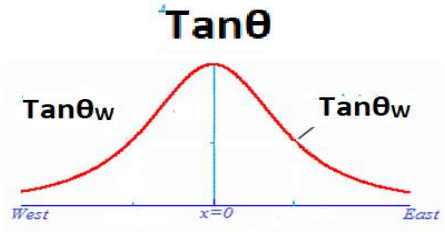


Fig.

PRECAUTIONS: -

1) The coil should be carefully adjusted in the magnetic meridian.

2) All the magnetic materials and current carrying conductors should be at a considerable distance from the apparatus.

3) The current passage in the coil should be of such a value as to produce a deflection of nearly 50^o -60^o

5) Parallax should be removed while reading the position of the pointer. Both ends of the pointer should be read.

6) The curve should be drawn smooth.

7) The pointer ends should be at zero each time before sending the current through the coil. If they are not at zero, the top of the glass cover should be gently tapped to bring them to zero.

RESULT:

It was observed that magnetic fields along the axis of a circular was found to be decreasing with increase of distance from center of circular coil. Also, the value of magnetic field from above two formula was found to be nearly equal.

VIVA-VOCE QUESTIONS

1. **What do you mean by magnetic meridian?**
2. **What is the purpose of commutator in the circuit?**
3. **Which current is passing through the coil i.e A.C or D.C**
4. **What is the difference between A.C & D.C current.?**
5. **Where do you observe magnetic field produced in this experiment?**
6. **What is tangents law**
7. **What is the limitation on deflection in magnetometer, while current is passing through the coil?**
8. **Where do you observe maximum magnetic field along the axis of coil.?**

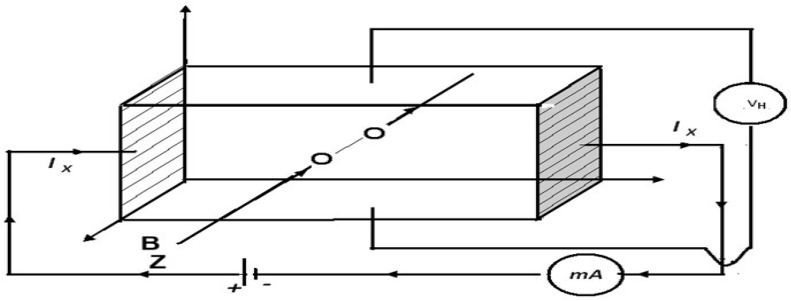
7. HALL EFFECT

Aim: To determine the hall coefficient (k_H), mobility of charge carriers(μ) and concentration of charge carriers(n) in a given material

Apparatus: Hall probe, Hall effect setup for measurement of current and voltage, electro-magnet, constant dc power supply to electro-magnet and Gauss meter.

Hall Effect: When magnetic field is applied perpendicular to a current carrying conductor, then voltage is developed in a direction both perpendicular to charge flow and applied magnetic field direction; is known as Hall effect. The developed voltage is known as Hall voltage(v_H).

CIRCUIT DIAGRAM



FORMULA:

1. Hall coefficient K_H is given by

$K_H = \left(\frac{V_H}{I_X}\right)\left(\frac{t}{B_Z}\right)\ \Omega - \frac{m^3}{Web}$ & it is measured from $V_H Verses\ I_x\ graph$ as

$$K_H = \frac{(slope\ of\ V_H Verses\ I_x\ graph)t}{B_Z}$$

$Here,\quad V_H = Hall\ voltage$

$t = thickness\ of\ the\ sample = 0.5mm = 0.5x10^{-3}$m

$B_Z = applied\ magnetic\ field\ in\ the\ z\ direction\ (B_Z = 0.25\ \text{Tesla})$

2. **Concentration of charged carriers (n) =** $\frac{1}{K_H e}\ Per\ m^3$

Where "e" is the charge of electron = 1.6X10^{-19} c

3. **Mobility of charge carriers (μ)= K_H σ** $m^2/volt - sec$

where σ = conductivity of sample = 1/ρ, ρ= resistivity of sample, given by

$$\rho = \frac{RA}{l} = \frac{R(bt)}{l} = \text{Rt}\ \Omega - \text{m}\ (since\ in\ our\ sample\ "l" = "b" = 5mm)\ \ Resistance "R" = \frac{V_x}{I_x}$$

THEORY:

Let us consider a rectangular plate of a conductor or semiconductor placed with its thickness along z-direction, the length along the x-direction and width along y-direction as shown in the above Figure1. Let a voltage be applied along x-direction such that it produce a current I_x, given by $\boldsymbol{I_x = J_x A}(where\ \boldsymbol{J_x} is\ current\ density \& \boldsymbol{A}\ is\ area\ of\ cross\ section)$ .Now let a magnetic field $\boldsymbol{B_Z}$ is applied along Z-direction. The applied magnetic field deflects the charge carriers towards positive Y-direction, and direction of deflection force can be known from Fleming's left-hand rule. If the given sample contain both +ve and –ve charges, then both will be deflected towards same side, leading to creation of potential difference between top and bottom face of the sample (i.e. along Y-direction), called hall voltage. After creation of potential difference charged particles moving along x- direction do not undergo any deviation from magnetic field and move in straight path. This is because the deflection force from magnetic field is balanced by force exerted by Hall electric field (i.e., force of repulsion exerted by already settled charges on the top surface of the sample).

At equilibrium the above two mentioned forces are equal.

$$\boldsymbol{i.e} \qquad \boldsymbol{F_H = F_B}$$

$$\boldsymbol{=> E_H\, e = B e v_d}$$

$$\boldsymbol{E_H = B_Z \left(\frac{J}{ne}\right) (since\ J = nev_d)}$$

$$\boldsymbol{E_H = B_Z \left(\frac{1}{ne}\right) J}$$

The term $\boldsymbol{\frac{1}{ne}}$ is called Hall coefficient denoted by $\mathbf{R_H}$. It is numerically equal to the developed Hall electric field when unit strength current is passing through the sample, in the presence of unit strength of externally applied magnetic field.

We know that the relation between E, V and 'd' is E = V/d

$$\boldsymbol{=> \frac{1}{ne} = \frac{V_H}{bB_Z J_x}}$$

$$\boldsymbol{=> \frac{1}{ne} = \frac{V_H A}{bB_Z I_x} \left[since\ J = \frac{I}{A}\right]}$$

$$\boxed{\boldsymbol{=> K_H = \frac{1}{ne} = \frac{V_H bt}{bB_Z I_x}\ [since\ area\ of\ the\ sample\ A = bt]}}$$

From the above expression we can calculate density of charged carriers.

We know that conductivity of the sample σ = neμ

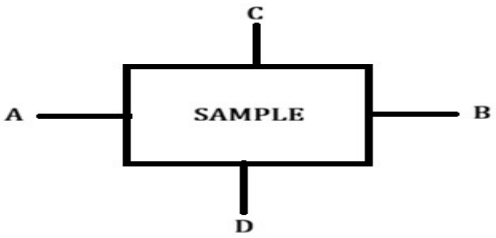
Where μ is mobility of charged carrier. It is defined as the drift velocity acquired by charged carrier under the application of unit electric field.

$$=> \mu = \frac{1}{ne}\sigma$$

$$=> \mu = K_H \sigma$$

PRACTICAL:

In the experiment Hall probe consists of a semiconductor sample in square shape having four pressure contacts as shown in fig. The two opposite ends are connected by a same color wire.



1. For the measurement of resistivity of sample connect terminals A & C to current ports of Hall effect setup, and other two wires (B & D) to voltage ports of Hall effect setup. Measure the voltage (V_x) for each current value and tabulate them.

2.Connect one set of same colour wires to current terminals and another set of colour wires to voltage terminals of Hall effect setup. Measure the error voltage (i.e., voltage in the absence of magnetic field) at different values of current passing through the sample. Measure the transverse voltage or Hall voltage in the presence of magnetic field for the same values of current passing through the sample, for the measurement of error voltage. The difference in the two voltages is the correct Hall voltage.

Table I : FOR THE MEASUREMENT OF RESISTIVITY

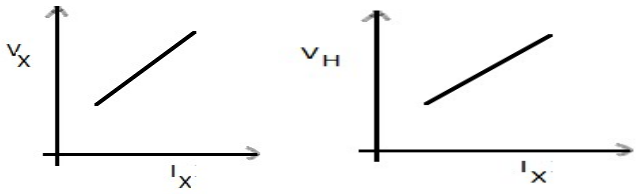
S.No.	Current I_x (mA)	Voltage V_x (mV)

Table - II: FOR THE MEASUREMENT OF HALL VOLTAGE.

S.No	Current I_x (mA)	Transverse voltage (OR) HALL VOLTAGE		True Transverse voltage (OR) True Hall voltage V_y= b-a (mV)
		Without magnetic field 'a' (mV)	With magnetic field 'b' (mV)	

Model graph: Plot the graph between I_x on x-axis, V_x on y-axis, we get a straight line.

(1) Plot the graph between I_x on x-axis, V_H on y-axis we get a straight line.



CALCULATION PART:

(1). Find the slope of straight line in the graph (i.e., I_x Vs V_x) and it is equal to resistance (R)

(2). We know that Resistivity $\boldsymbol{\rho} = \frac{\boldsymbol{RA}}{\boldsymbol{l}} = \frac{\boldsymbol{Rbt}}{\boldsymbol{l}} = \boldsymbol{Rt}[\boldsymbol{since\ l = b}]\ \Omega - \boldsymbol{m}$

(3). Conductivity $\boldsymbol{\sigma} = \frac{\mathbf{1}}{\boldsymbol{\rho}}\ \Omega - \boldsymbol{m}^{-1}$

(4). Find the slope of $\boldsymbol{I_x\ Verses\ V_H}$ graph, put this value in $\boldsymbol{K_H}$ expression.

(5).$\boldsymbol{K_{H=}\frac{V_H t}{I_x B_z}} = (\boldsymbol{slope\ of\ I_x V_s V_H})\frac{\boldsymbol{t}}{\boldsymbol{B_z}}$**Ω-m³/Web**

(6). $\boldsymbol{Concentration\ of\ charged\ carriers(n)} = \frac{\mathbf{1}}{\boldsymbol{K_H e}}/\boldsymbol{m}^3$ (Since $\mathbf{k_H} = \frac{\mathbf{1}}{\mathbf{ne}}$)

(7). $\boldsymbol{Mobility\ of\ charged\ carrier}(\mu) = \boldsymbol{K_H \sigma}\ \ \boldsymbol{m^2/volt - sec}$

Sample dimensions are l = 5mm, b = 5mm = 5X10^{-3}m, t =0.5mm = 0.5X10^{-3}m

PRECAUTIONS:

1 Increase slowly the current through electromagnet from power supply (max up to 2A).

2 Before switching off power supply, reduce current to zero and the switch off.

3 Keep the probe in the Gauss meter at the center of pole pieces and rotate till it shows maximum reading for the measurement of magnetic field.

RESULT:

1.$\boldsymbol{Hall - coefficient\ K_{H=}} - - - - - - - - \Omega - \mathbf{m^3/Web}$

2.$\boldsymbol{Conductivity\ of\ the\ sample\ \sigma} = \frac{\mathbf{1}}{\boldsymbol{\rho}} - - - - - - \Omega - \boldsymbol{m}^{-1}$

3.$\boldsymbol{Concentration\ of\ charged\ carriers\ 'n'} - - - - - - - - \boldsymbol{Per\ m^3}$

4.$\boldsymbol{Mobility\ of\ charged\ carrier}(\mu) = \boldsymbol{K_H \sigma} = - - - - - - -\ \ \boldsymbol{m^2/volt - sec}$

VIVA-VOCE QUESTIONS

1.What is Hall effect
2. Does charged carriers undergo acceleration under the application of magnetic field perpendicular to its motion.
3. What are the various applications Hall effect.
4. Define Hall coefficient
5. Define mobility of charged carrier

8. LCR SERIES RESONANCE CIRCUIT

AIM: To determine resonating frequency and quality factor in the LCR series circuit.

APPARATUS: A signal generator, inductor, capacitor, ammeter, resistors, AC milli ammeter.

FORMULA: When L, C & R are connected in series, the resonance frequency f_r is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}}\ \text{Hz}$$

Here "L" is self-inductance of inductor measured in Henrys

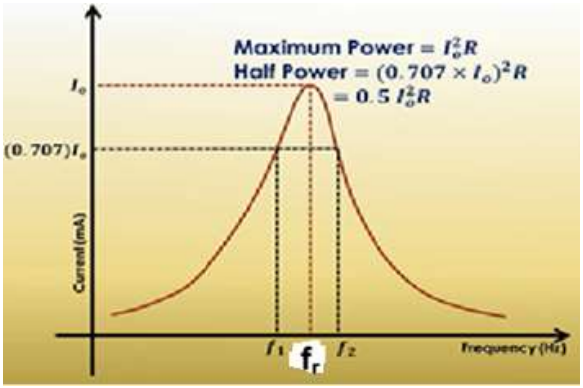
"C" is capacitance of capacitor measured in Farads

The **quality factor (Q-factor)** in an LCR circuit measures the circuit's efficiency and selectivity at resonance, directly impacting how sharply it can distinguish a specific frequency and how effectively it stores energy versus dissipates energy. It is measured with the formula below

$$\mathbf{Q=\frac{\omega_0 L}{R}=\frac{2\pi f_r L}{R}=\frac{1}{R}\sqrt{\frac{L}{C}}}\ \ \mathbf{(\text{ since } f_r = \frac{1}{2\pi\sqrt{LC}})}$$ It is dimensionless quantity

It is also measured from graph as $\mathbf{Q=\frac{f_r}{\Delta f}} = \frac{f_r}{f_2 - f_1}$

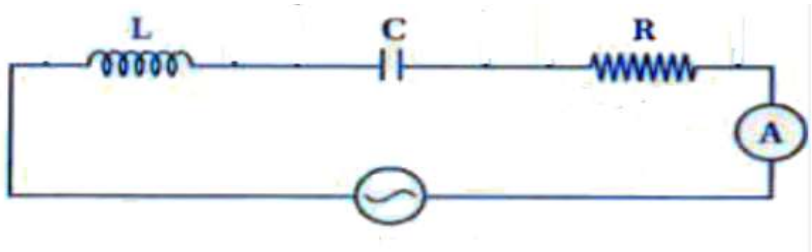
Here Δf is band width=difference between frequencies where the power falls to half of its maximum value at resonance.



THEORY:-

Circuits containing an inductor L, a capacitor C, and a resistor R, have special characteristics useful in many applications. Their frequency characteristics (impedance, voltage, or current vs. frequency) have a sharp maximum or minimum at certain frequencies. These circuits can hence be used for selecting or rejecting specific frequencies and are also called tuning circuits. These circuits are therefore very important in the operation of television receivers, radio receivers, and transmitters. In this section, we will present two types of LCR circuits, viz., series and parallel, and discuss the formulae applicable for typical resonant circuits. A series LCR circuit includes a series combination of an inductor, resistor and capacitor whereas; a parallel LCR circuit contains a parallel combination of inductor and capacitor with the resistance placed in series with the inductor. Both series and parallel resonant circuits may be found in radio receivers and transmitters.

SERIES RESONANCE CIRCUIT: -



When an alternating e.m.f $E = E_0 sin\omega t 0$ was applied to circuit having an inductance L, capacitance C and resistance R in series as shown in fig. The current in the circuit at any instant of time "t" is given by the following equation

$$I = I_0 Sin(\omega t - \varphi)$$

Where it can also be proved that the maximum current I_0 is

$$\boldsymbol{I_0 = \frac{E_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} - - - - - (1)}$$

From the above expression (1) the impedance of circuit is given by is

$$\boldsymbol{Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

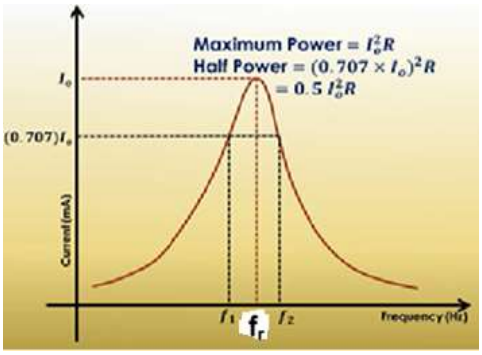
In L - C - R series circuit, resistance offered by a capacitor called capacitive reactance, represented by $\boldsymbol{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}}$ decreases with increasing applied a.c. frequency, whereas resistance offered by inductor called inductive reactance denoted by $\boldsymbol{X_L = \omega L = 2\pi f L}$ increases with increase of applied a.c. frequency . As a.c. frequency is increased at a particular frequency inductance reactance ($\boldsymbol{\omega L}$) equals to capacitive reactance, $\boldsymbol{(X_C)}$ i.e $\boldsymbol{\omega L = \frac{1}{\omega C}}$ also at that frequency impedance(Z) of the L - C - R series circuit(i.e effective resistance offered by all elements in the circuit) becomes minimum and current passing through the circuit reaches to a maximum valve. The frequency at which impedance becomes minimum is called resonant frequency. After resonant frequency $\boldsymbol{\omega L \neq \frac{1}{\omega c}}$, impedance of the circuit is not minimum, hence current in the circuit falls off from maximum value The word resonance is used because at that frequency forced frequency from input a,c frequency is matches with natural frequency of L-C-R series circuit.

At resonance frequency $\boldsymbol{\omega L = \frac{1}{\omega c}}$

$$\boldsymbol{=> \omega = \frac{1}{\sqrt{LC}}}$$

$$\boldsymbol{=> f_r = \frac{1}{2\pi\sqrt{LC}}\ Hz (since\ \omega = 2\pi f)}$$

The above equation shows that the resonant frequency depends on the product of L and C and does not depend on R. The variation of the peak value of current with the frequency of the applied e.m.f is shown in Fig. below.



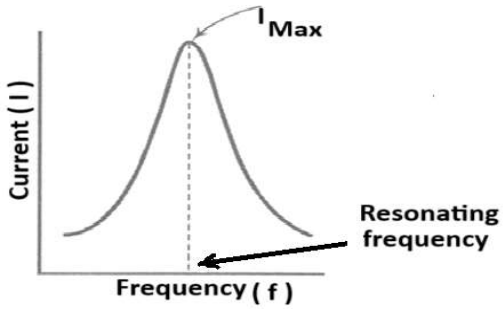


Fig-1

This action of current shooting to maximum at f =resonating frequency (fr) is looked upon as if, the circuit is accepting a frequency fr better than any other frequencies. Hence a series LCR circuit is referred to as 'acceptor circuit'. This property is used in radio receivers in selecting a broadcasting station of interest. When we turn the tuning knob, we are changing the capacitance continuously. Once we hear the sound broadcast from particular station, it means that the capacitance value in the receiver set has just become right so as to have the resonance frequency fr exactly same as the carrier frequency of the transmitting station. The peak in the curve in Fig. 1 will become less & less pronounced with increasing resistance. For a very high resistance, the resonance peak will be very small & the curve is almost flat. It is called flat resonance.

Since a resistor simply dissipates the power, a sharp resonance curve indicates that 'out of the energy supplied to the circuit by the ac source, less is dissipated & more is stored'. This property is referred to as the 'Quality factor of the circuit'. The quality factor of an LCR circuit denoted as Q is defined as "the ratio of the energy stored in the circuit to the energy loss per cycle". A higher Q-factor means **sharper resonance**, allowing the circuit to strongly respond to a narrow band of frequencies while rejecting others, which is crucial for applications like filters and radio receivers. It is a dimensionless quantity. To know quantitatively, Q is defined by the equation,

$$\mathbf{Q}=\frac{\omega_0 L}{R}=\frac{2\pi f_r L}{R}=\frac{1}{R}\sqrt{\frac{L}{C}}$$ **(since** $f_r = \frac{1}{2\pi\sqrt{LC}}$ **)** It is dimensionless quantity

It is also measured from graph as $\mathbf{Q}=\frac{f_r}{\Delta f}$

Here Δf is band width=difference between frequencies where the power falls to half of its maximum value at resonance.

PROCEDURE:

1. Connect all L,C,& R are connected series as shown fig.

2. Set the values of L, C, value from the experimental setup, and calculate theorical resonance value using formula. $\boldsymbol{f_r = \frac{1}{2\pi\sqrt{LC}}}$

3. Slowly vary the a.c frequency and note down current in circuit (at one "R" value), till you observe resonance in the circuit, and continue to note down the reading beyond $\mathbf{f_r}$ values. Repeat the same observation at another value of "R".

4. Draw a graph frequency of a,c signal on x-axis and corresponding current value on Y-axis, as shown in above fig. 1

5. Draw a straight line on Y-axis at 0.707 $\mathbf{I_{Max}}$ i.e it is the current at which power drops to 50% of its maximum at resonant frequency for measuring bandwidth of LCR circuit

TABLE FORM

L = _____ mH C = _____ μF.

S.No	Applied frequency f Hz	Current in circuit (mA)		
		R=	R=	R=

RESULT :

Resonance frequency for series LCR circuit =_____Hz

Quality factor measured from observation_____, from graph_____

VIVA-VOCE QUESTIONS

1. What are "L", "C", & "R", represent in the circuit.
2. Define impedance of a circuit.
3. What is the difference between impedance & resistance of a circuit.
4. What is inductive reactance and what happens to its value under increasing Frequency of A.C. signal.
5. What is capacitive reactance and what happens to its value under increasing Frequency of A.C. signal.
6. How do you identify resonance in LCR circuit.
7. At which frequency of applied signal, inductive & capacitive reactance are equal .
8. Define resonance
9. Where do you observe application of LCR circuit , in day to day life
10. Define quality factor, bandwidth, of LCR circuit.
11. Where you find practical importance of LCR circuit in day to day life

9. FORBIDEN ENERGY GAP OF SEMICONDUCTOR

AIM: To determine the energy gap of material of PN junction diode by connecting in reverse bias

Apparatus : Electric heater Transformer oil Ge/Si diode DC Power supply, micro ammeter, voltmeter, thermometer & retard stand.

FORMULA: When PN-Junction diode is reverse biased, the expression for reverse saturation current(Is) is given by

$$I_s = A\left(e^{-E_G/\eta kT}\right) \quad \text{----------(1)}$$

Here Eg is energy gap of the material,

"**η**" is a constant depends on material,

"**η**" =1 for Germanium diode and **η**=2 for silicon diode,

In this experiment, the PN junction is made from germanium diode, hence the expression for reverse saturation current is given by

$$I_s = A\left(e^{-E_G/kT}\right) \quad \text{----------(2)}$$

Apply ting logarithm on both sides of the above equation, we get,

$$log_e I_s = log_e A - \left[\frac{E_G}{K}\right]\frac{1}{T}$$

$$log_{10} I_s = \left[\frac{-E_G}{(2.303)K}\right]\frac{1}{T} + log_{10} A \quad \left[\begin{matrix} since\ log_e I_s = 2.303\ log_{10} I_s\ and \\ log_e A = 2.303 log_{10} A \end{matrix}\right]$$

When a graph is drawn between $\boldsymbol{log_{10} I_s}$ on y-axis and $\frac{1}{T}\mathbf{x10^3}$ on x-axis we get a straight line having a negative slope as show in Fig. The slope of the graph is given by

$$m = \frac{E_G}{(2.303)K}$$

Energy gap of the semiconductor material can be determined by substituting the Boltzmann constant "k"=8.62x10^{-5} eV/K in the above expression for slope, we get

$$\boldsymbol{E_G = (slope)\ x\ (2.303)k \quad eV}$$

Introduction:

We know that in a single atom, energy levels of electrons are sharply defined. A solid is a close packing of atoms with rigid shape. When atoms are grouped together to form a solid, each sharply defined energy level of electron is split into group of energy levels called band. The number of energy levels in band equal to number of atoms grouped in that solid. That is once

solid is formed we have various band of energy levels, in place of single energy levels. This is the basic concept in band theory of solids. Energy band which contains valence electrons is called VALENCE BAND, similarly a band which contains conduction electrons is called CONDUCTION BAND. The energy difference between valence band and conduction band is called energy gap or forbidden energy gap of the solid material, measured in electron volts. The word forbidden (means not allowed) is used because electron cannot have energy levels in between valence band and conduction band. According to band theory of solids, based on energy gap, solid materials are categorized as 1.Metals, 2.Semiconductors, and 3.Insulators

1.Metals: Solid materials in which valence band conduction band are merged with one another, or Energy gap E_g =0, behaves as metal. Metals are characterized by positive temperature coefficient of resistance, i.e Electrical resistance of metals increases with increase of temperature.

2.Semiconductors: Solid materials whose energy gap is between 0 and 3.2 eV, they are called semiconductors. Semiconductor materials are materials which have their electrical resistivity values in between metals and insulators. These semiconductor materials are also characterized by a property i.e they possess negative temperature coefficient of resistance, i.e their resistance decreases with increase of temperature, this is because, as we increase temperature, electrons in valence band absorb our supplied heat energy, and there are excited to conduction band. As we supply more heat energy, the number of electrons in conduction increases i.e conductivity increases or resistance decreases.

3.Insulators: Solid materials whose energy gap is above 3.2 eV, are called insulators. It is difficult to transfer electrons from valence band to conduction band.

The classification of solids based on energy gap is as shown in below Fig.

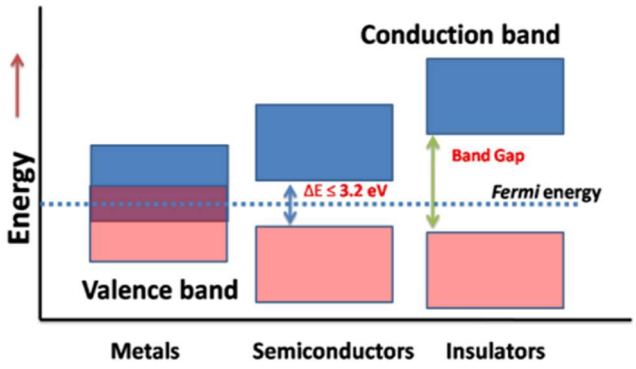


Fig.1. Energy Gap in Metals, Semi-conductors and Insulators

Experiment:

To determine the energy band gap of a semi-conducting material, we study the variation of its resistance with temperature. In this experiment, a semiconductor diode is kept under reverse biased. The reason for reverse bias, is that the current flowing through the PN junction is quite small and internal heating of the junction does not take place.

When PN-Junction diode is reverse biased, the expression for reverse saturation current (Is) is given by

$$I_s = A\left(e^{-E_G/\eta kT}\right) \quad \text{----------(1)}$$

Here Eg is energy gap of the material,

"**η**" is a constant depends on material,

"**η**" =1 for Germanium diode and **η**=2 for silicon diode,

In this experiment, the PN junction is made from germanium diode, hence the expression for reverse saturation current is given by

$$I_s = A\left(e^{-E_G/kT}\right) \quad \text{----------(2)}$$

Apply ting logarithm on both sides of the above equation, we get,

$$\log_e I_s = \log_e A - \left[\frac{E_G}{K}\right]\frac{1}{T}$$

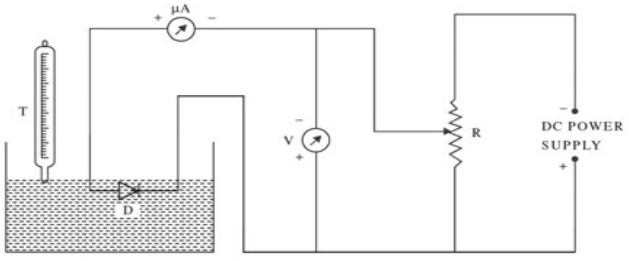
$$\log_{10} I_s = \left[\frac{-E_G}{(2.303)K}\right]\frac{1}{T} + \log_{10} A \quad \left[\begin{matrix} since\ \log_e I_s = 2.303\log_{10} I_s\ and \\ \log_e A = 2.303\log_{10} A \end{matrix}\right]$$

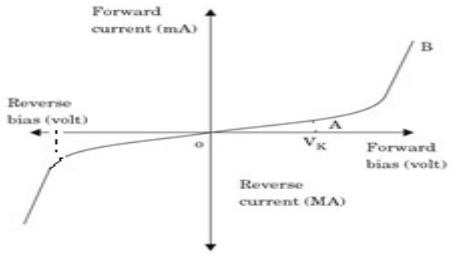
When a graph is drawn between $\log_{10} I_s$ on y-axis and $\frac{1}{T}$ **x10^3** on x-axis we get a straight line having a negative slope as show in Fig. The slope of the graph is given by

$$m = \frac{E_G}{(2.303)K}$$

Energy gap of the semiconductor material can be determined by substituting the Boltzmann constant "k"=8.62x10^{-5} eV/K in the above expression for slope, we get

$$E_G = (slope)\ \mathbf{x}\ (2.303)k \quad eV$$





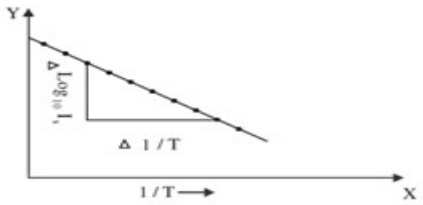
Procedure:

1. Wire the connections as per the circuit diagram.
2. Insert the thermometer into the opening of Bekelite cap.
3. Now switch on the oven and allow the oven temperature to rise to 75° C. As temperature reaches to this value switch off the oven. The temperature will rise up to 85C to 90C.
4. After some time, the temperature will begin to fall. Now fix the voltage at 5volts.
5. Note down the current at various temperatures
6. Take current in μA and temperature reading in Kelvin in steps of 5μA fall in current.

TABLE FOR OBSERVATIONS

S.NO.	CURRENT I_s IN μA	TEMPERATURE IN ^{O}C	TEMPERATURE IN KELVIN (T)	$\frac{1}{T}$	$log_{10} I_s$

MODEL GRAPH: A graph is drawn between $log_{10} I_s$ on y-axis and $\frac{1}{T}$ x10^3 on x-axis we get a straight line as show in Fig. and measure the slope of the graph.



Result: Energy gap of the semiconductor diode is determined both during heating and during cooling is given by

$$E_G = \qquad eV$$

VIVA-VOCE QUESTIONS

1. What do you mean by energy gap of a semiconductor

2. What happens to resistance of a semiconductor, when its heated. Justify your answer

3. How do you differentiate metal from semiconductor, when both of them were heated to same temperature.

3. **What do you mean by reverse biasing a diode.**

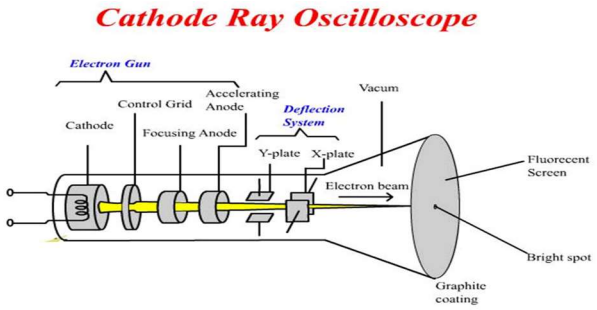
10. CATHODE RAY OSCILLOSCOPE

AIM:- To measure and compare voltage and frequency of given A.C. signal

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APPARATUS:- A C.R.O and a signal generator.

BLOCK DIAGRAM OF CRO: The various main parts of CRO are shown in Fig. below



THEORY :-

Cathode ray oscilloscope is one of the most useful electronic equipment, which gives a visual representation of electrical quantities, such as voltage and current waveforms in an electrical circuit. It utilizes the properties of cathode rays of being deflected by an electric and magnetic fields and of producing scintillations on a fluorescent screen. Since the inertia of cathode rays is very small, they are able to follow the alterations of very high frequency fields and thus electron beam serves as a practically inertia less pointer. When a varying potential difference is established across two plates between which the beam is passing, it is deflected and moves in accordance with the variation of potential difference. When thiselectron beam impinges upon a fluorescent screen, a bright luminous spot is produced there which shows and follows faithfully the variation of potential difference. When an AC voltage is applied to Y-plates, thespot of light moves on the screen vertically up and down in straight line. This line does not reveal the nature of applied voltage waveform. Thus to obtain the actual waveform, a time-base circuit is necessary. A time- base circuit is a circuit which generates a saw-tooth waveform. It causes the spot to move in the horizontal and vertical direction linearly with time. When the vertical motion of the spot produced by the Y-plates due to alternating voltage, is superimposed over the horizontal sweep produced by X-plates, the actual waveform is traced on the screen.

PROCEDURE:-

STUDY OF WAVEFORMS:

To study the waveforms of an A.C voltage, it is led to the y – plates and the time base voltage is given to the X-plates. The size of the figure displayed on the screen, can be adjusted suitably by adjusting the gain controls. The time base frequency can be changed, so as to accommodate one, two or more cycles of the signal. There is a provision in C.R.O to obtain a sine wave or a square wave or a triangular wave.

MEASUREMENT OF D.C.VOLTAGE : -

Deflection on a CRO screen is directly proportional to the voltage applied to the deflecting plates. Therefore, if the screen is first calibrated in terms of known voltage.i.e. the deflection sensitivity is determined , the direct voltage can be measured by applying it between a pair of deflecting plates. The amount of deflection so produced multiplied by the deflection sensitivity, gives the value of direct voltage.

MEASUREMENT OF A.C VOLTAGE : -

To measure the alternating voltage of sinusoidal waveform, The A.C. signal, from the signal generator, is applied across the y – plates. The voltage(deflection) sensitivity band switch (Y-plates) and time base band switch (X-plates) are adjusted such that a steady picture of the waveform is obtained on the screen. The vertical height (l) i.e. peak-to-peak height is measured. When this peak-to-peak height (l) is multiplied by the voltage(deflection) sensitivity (n) i.e. volt/div, we get the peak-to-peak voltage (2Vo). From this we get the peak voltage (Vo). The rms voltage V_{rms} is equal to Vo/ 2 . This rms voltage Vrms is verified with rms voltage value, measured by the multi-meter.

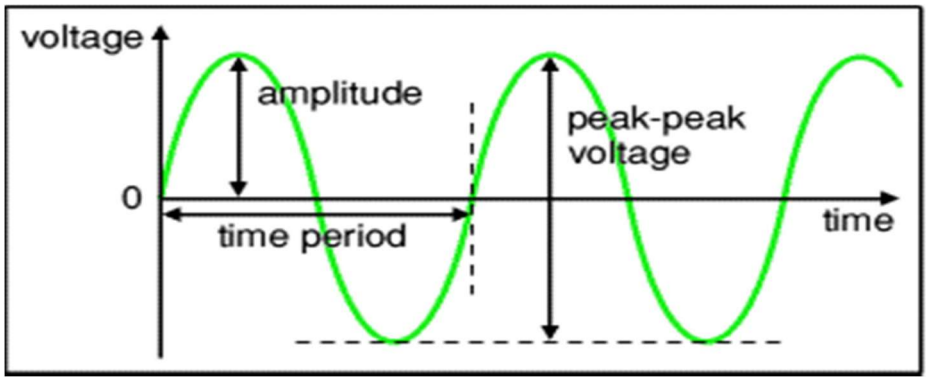


TABLE - I FOR VOLTAGE COMPARISION

S.NO	APPLIED VOLTAGE "A" VOLTS	HEIGHT OF THE SIGNAL "X"	VOLT/DIV "Y"	OBSERVED VOLTAGE "B" =XY (VOLTS)	DIFFERENCE IN VOLTAGE A≈B

MEASUREMENT OF FREQUENCY : -

An unknown frequency source (signal generator) is connected to y- plates of C.R.O . Time base signal is connected to x – plates (internally connected) . We get a sinusoidal wave on the screen, after the adjustmentof voltage sensitivity band switch (Y-plates) and time base band switch (X-plates). The horizontal length(l) between two successive peaks is noted. When this horizontal length (l) is multiplied by the time base(m) i.e. sec/div , we get the time-

period(T).The reciprocal of the time-period(1/T) gives the frequency(f). This can be verified with the frequency, measured by the multi-meter.

TABLE - 2 FOR FREQUENCY COMPARISION

S.NO	APPLIED FREQUENCY "A" Hz	WIDTH OF THE SIGNAL "X"	TIME/DIV "Y"	TIME PERIOD T=XY Sec	OBSERVED FREQUENCY B=1/T Hz	DIFFERENCE IN FREQUENCY A≈B

PRECAUTIONS :-

1) The continuity of the connecting wires should be tested first.
2) The frequency of the signal generator should be varied such that steady wave form is formed.
3. An oscilloscope should be handled gently to protect its fragile (and expensive) vacuum tube.
4. Oscilloscopes use high voltages to create the electron beam and these remain for some time after switch-off. For your own safety do not attempt to examine the inside of an oscilloscope.

RESULT: - The voltage, and frequency of given ac signal were measured & compared, and they were found nearly equal.

VIVA-VOCE QUESTIONS

1.What are the various uses of CRO

2. What is a signal generator

3. Define time period & frequency of signal.

4. What are the main parts CRO.

CHARACTERISTICS OF A PHOTO DIODE

AIM: To measure responsivity (R_λ) , Quantum Efficiency (QE) and I-V characteristic Curves of Ga-As based photo diode (PD) in the visible region.

APPARATUS: Photo diode experimental set-up (it consists of 0-3V regulated power supply, 0-2mA digital dc current meter, 0-20V digital dc volt meter), white light LED module with variable light power, and photo diode LED type.

FORMULA

Responsivity (R_λ)

The degree of response of a silicon photodiode to light is a measure of its sensitivity, and it is defined as the ratio of the photo current I_{PD} to the incident light power P at a given wavelength. This is usually expressed in units of A/W (current over power)

$R_\lambda = \frac{I_{PD}}{P}$ Where I_{PD} is photo diode current and P is the light input power

Quantum Efficiency (QE):

Quantum efficiency is defined as the fraction of the incident photons that contributes to photocurrent. It is related to responsivity as

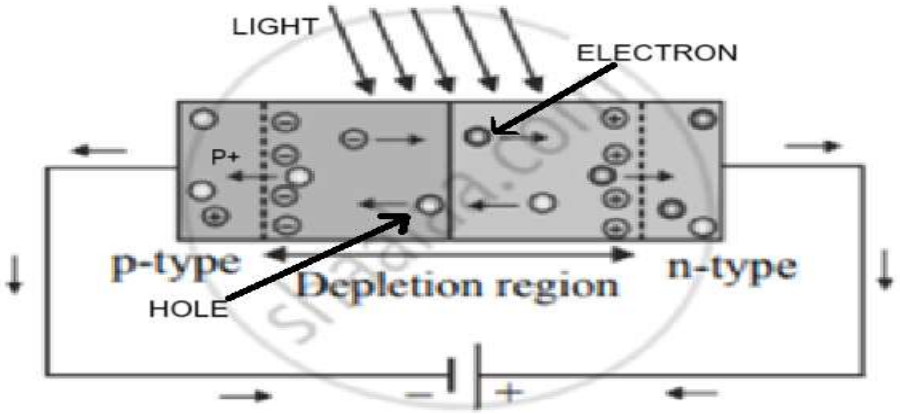
$$Q\ E = 1240 \frac{R_\lambda}{\lambda}$$

Here λ is the average wavelength of the white light source, which is 575nm.

THEORY:

Photo diode belongs to photo detection devices. Photo diode detects the incident light energy which falls on it , by converting it into electrical energy. It is basically a PN Junction diode, operated under reverse bias mode. Even though Photo diode is similar to a ordinary PN junction diode, but it is different in design point of view, i.e doping of P , N- regions and in biasing aspects. It consists of heavily doped P region (P+) on top, depletion region at middle and N-region at bottom. When light photon having energy greater than energy gap of semiconductor, falls on photo diode, electron – hole pairs are created in all P, depletion region and N- region by absorbing incident light photon energy. The electron-hole pairs created in junction region are separated by junction electric field, i.e electrons are dragged into N-region, similarly holes are dragged into

P-region, producing photo current in the external circuit. Electron and holes pairs (EHP) which are created very close to junction region i.e within the diffusion length of carries (diffusion length is the free distance travelled by the charged carrier before it recombines with opposite carrier) are alone able cross the junction barrier, whereas other EHP created beyond diffusion length from junction are unable to cross the junction, because they undergo recombination with opposite carrier, before reaching the junction. The photo current produced in photo diode is EHP's created in depletion region, and it varies linearly with incident light power. Depending on the wavelength of range to be detected, responsivity and speed, photo diodes are made with different type of materials.



Optical Characteristics

Responsivity (R_λ):

The degree of response of a silicon photodiode to light is a measure of its sensitivity, and it is defined as the ratio of the photo current I_{PD} to the incident light power P at a given wavelength. This is usually expressed in units of A/W (current over power)

$$R_\lambda = \frac{I_{PD}}{P}$$

Where I_{PD} is photo diode current and P is the light input power

In other words, it is a measure of the effectiveness of the conversion of the light power into electrical current. It varies with the wavelength of the incident light as well as applied reverse bias and temperature. By drawing a graph of PD current variation with

input LED power, one can accurately determine the value of responsivity, as given by the slope of the straight line representing I_{PD} verses P curve.

Responsivity increases slightly with applied reverse bias due to improved charge collection efficiency of the photodiode. Also, it varies due to change in temperature. This is due to decrease or increase of the band gap, because of increase or decrease in the temperature respectively. Spectral responsivity may vary from one PD to the other and it is also dependent on wavelength of the light.

Quantum Efficiency (QE):

Quantum efficiency is defined as the fraction of the incident photons that contributes to photocurrent. It is related to responsivity as

$$Q\,E = 1240\,\frac{R_\lambda}{\lambda} \quad \text{--------(1)}$$

Here λ is the average wavelength of the white light source, which is 575nm.

I-V Characteristics

The current-voltage (I-V) characteristic of a photodiode is a set of curves relating the voltage across the junction to the current flowing through it. When the photodiode is forward biased, there is an exponential increase in the current similar to rectifier diode. When a reverse bias is applied, a small reverse saturation current appears. The forward diode current is given by

$$I_D = I_{sat}\left(e^{\frac{qV}{kT}} - 1\right) \quad \text{-----(2)}$$

The current through the illuminated PD is given by $I_{PD} = I_P + I_{SAT} \approx I_P$

Where I_P is photon current (current due to illumination),

I_{SAT} is reverse saturation current.

Equation- (2) shows that in the reverse bias case the conduction depends entirely on the illumination. Hence photo diode current is proportional to the incident light intensity. The photo diode current also follows the inverse square law and depends on the wavelength of the light. Hence there is no exact formula for estimating photo diode current in terms of an experimentally measurable quantity. As the applied reverse bias voltage increases, there is a sharp increase in the photo current and the device will be damaged permanently. This voltage is called breakdown voltage. The magnitude of the

breakdown voltage varies with the type of PD. It lies in the range 5 to 100V. Hence one should not apply too much reverse bias.

Experimental Procedure

The experiment consists of two parts

Part-A: Determination of Responsivity

Part-B: Determination of I-V Characteristics

Part-A: Determination of Responsivity



Fig-2 Light arrangement of the experimental set-up

The above Figure shows the light arrangement of the experimental setup. The white light LED and PD are placed face-to-face 10cm, by varying the pot in the emitter circuit, the LED current is varied. A dial is provided for the potentiometer which directly reads the LED input power ($P_{LED}=V_{LED} * I_{LED}$).

1. The LED (white light) and PD are placed face to face as shown in Figure-2, and the light arrangement is switched on. LED power is set to 10mW by turning the knob to its minimum position. After ensuring that the LED is glowing and while noting the PD current in the meter, the cover is placed so that any external light will not affect the readings. Positive terminal of the PD (p) is connected to the negative terminal of the power supply and negative of the PD is connected to positive terminal of the power supply. This reverse biases the photo diode.

2.The voltage across PD is set to -1V by varying 0-3V power supply. The PD current IPD is noted. V_{PD} = -1V, I_{PD} =- 3.3mA

3. The LED power is increased to 11mW and V_{PD} is again set to -1V and the corresponding PD current is noted in Table-1.0

4.The trial is repeated by varying the input power to 12mW, 13mW etc. reaching up to 50mW. In each case V_{PD} is set to -1V and I_{PD} is noted in Table-1.

5.A graph showing the variation of LED power on X-axis and PD current on Y axis is drawn as shown in below Figure-3. A straight line graph is obtained, slope of which gives the value of responsivity.

TABLE-1

P_{LED} (mW)	I_{PD} (mA)	R_λ (A/W)

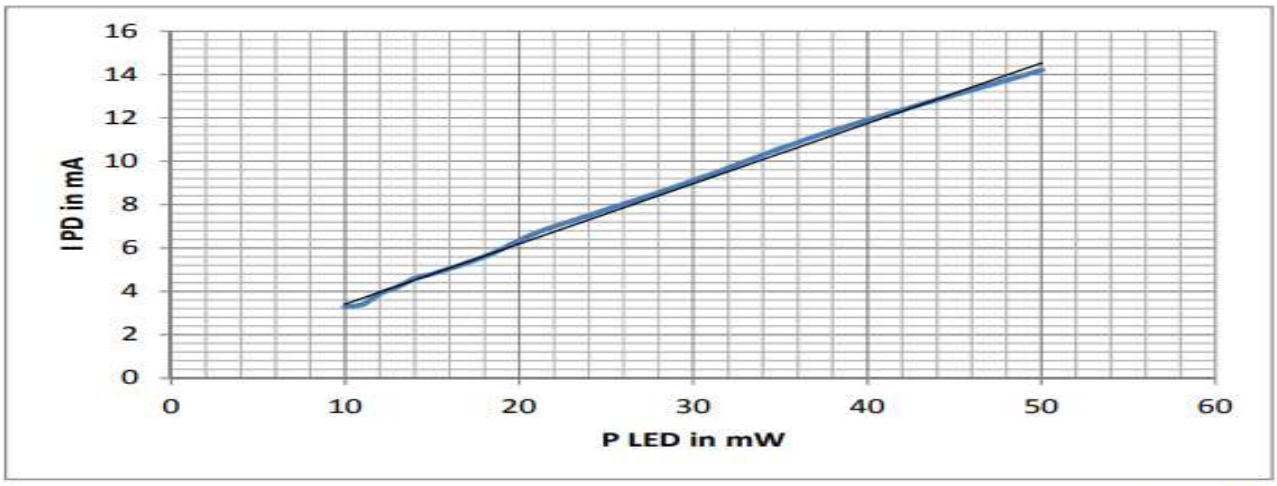


Fig-3: Variation of PD current with LED power (V_{PD}=-1V)

The external conversion efficiency of white LED is 0.9 or 90%, it means LED delivers only 90% of input energy i.e electrical energy, into optical energy. In case of incandescent light source i.e ordinary bulb converts only 40% of input electrical energy into light energy, and remaining input energy is wasted in the form of heat. Hence to get exact responsivity of photo diode, we must divide the slope of Fig-3 by 0.9

Exact Responsivity, R_λ = (Slope of the graph P_{LED} Vs I_D) /0.9

Quantum efficiency (QE) is calculated using equation-1. Where is the average wavelength of the white light source, given as 575 nm (data provided by the manufacturer)

$$Q\,E = 1240\,\frac{R_\lambda}{\lambda}$$

$$Q\,E = 1240\,\frac{R_\lambda}{575}$$

Part-B: Determination of I-V Characteristics of PD

In this part of the experiment PD current and voltage are recorded for different LED input powers.

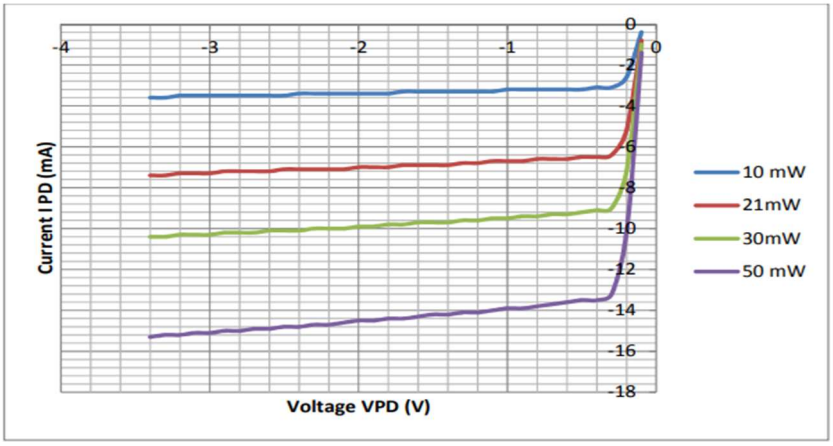
The LED power is set to 10mW on the dial and V_{PD} is set to -0.10V and the corresponding I_{PD} is noted I_{PD}=- 0.4 mA 8. The trial is repeated by increasing V_{PD} in suitable steps up to a maximum of -3.4V. The corresponding I_{PD} values are noted in below Table-2.

The experiment is repeated by increasing the LED power to 20, 30, 40 and 50mW in steps. In each case variation in V_{PD} and corresponding I_{PD} are noted in Table-2.

V_{PD} (v)	I_{PD} (mA)			
	P_{LED} =14mW	P_{LED} =21mW	P_{LED} =25mW	P_{LED} =30mW

Variation of PD voltage with current*
(Negative voltage and current indicate the reverse bias).

A graph is drawn taking V_{PD} along X-axis and I_{PD} along Y-axis as shown in Figure-8. The equal spacing between characteristic curves indicates linearity of photo current with light intensity which is clearly indicated in below Figure



Results:

Parameters	Expt.	Typical
Responsivity (R_λ) at 575nm		
Quantum Efficiency (QE)		

PRIOR PREPARATION / WRITEUP FOR EXTERNAL LAB EXAM

1. COMPOUND PENDULUM

AIM : To determine acceleration due to gravity (g)at a place using compound pendulum.

APPARATUS: Compound pendulum, knife edges, telescope, stop watch, meter scale.

FORMULA: Time period of oscillation of a physical pendulum or compound pendulum is given by

$$T = 2\pi\sqrt{\frac{K^2+D^2}{gD}}\ Sec$$

Compare the above formula with time period of oscillation of a simple pendulum. i.e.

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

Here $\mathbf{L} = \sqrt{\frac{K^2+D^2}{D}}$ is called length of equivalent simple pendulum. K is radius of gyration; 'D' is distance of the point of suspension from center of gravity. The value of " L " is estimated from a graph drawn between distance of point of suspension (l) verses time period of oscillation (T)

From the above formula acceleration due to gravity is given by $\mathbf{g = 4\,\pi^2\left(\frac{L}{T^2}\right)}$ **cm/s²**

TABULAR FORM FOR THE DETERMINATION OF TIME PERIOD

S.No	Distance of knife edge from one end of the bar."D"	Time taken for 20 oscillations			Time period T=t/20 Sec
		Trail 1	Trail 2	Mean time (t) sec	

TABULAR FORM FOR THE DETERMINATION OF EQUIVALENT LENGTH OF SIMPLE PENDULUM

S.No	Time period "T"	T^2	AC	BD	$L = \frac{AC+BD}{2}$	$\frac{L}{T^2} = Constant$

Graph:

1. Draw a graph between "D" values on x-axis and corresponding "T" values on Y- axis, then we get the following nature of graph.(Fig 1). Draw a straight line, at one particular "T" value, then it intersect the graph at four points and mark them as A,B,C,& D

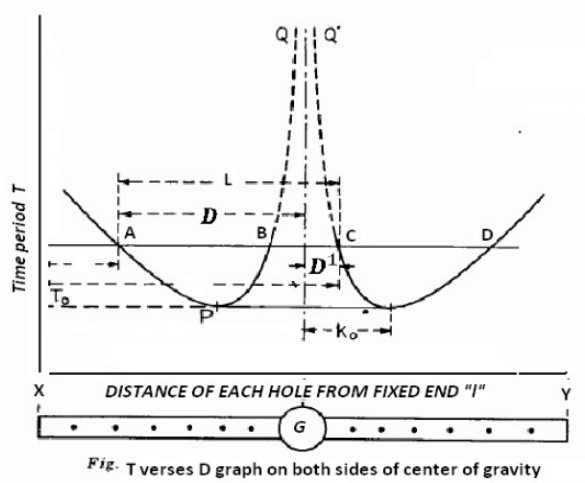


Fig. T verses D graph on both sides of center of gravity

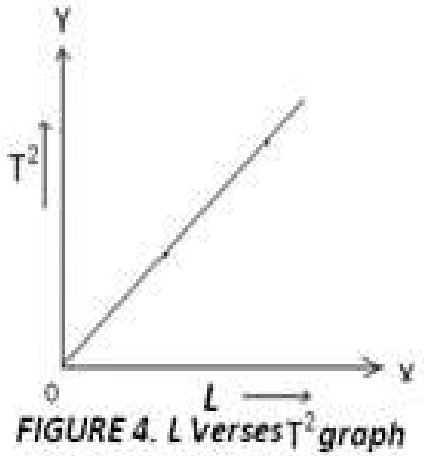


FIGURE 4. L Verses T^2 graph

GRAPH 2.

A graph is drawn between "L" values on X-axis and corresponding "T^2" values from table 2, on Y-axis, and then the nature of graph is as shown in Fig4

PRECAUTIONS: 1. Angular displacement of the pendulum should be confined to below 10^o
2. Pendulum should oscillate only in vertical plane, without wobbling.
3. Knife edge should rest on horizontal surface only.

---

2. TORSIONAL PENDULUM

AIM: To determine the rigidity modulus of the material of the wire by the method of oscillations.

APPARATUS: Circular disc with chuck, given wire (suspension wire), stop clock, two equal cylindrical masses, screw gauge, vernier calipers and meter scale.

FORMULA: Rigidity modulus of given wire using torsional pendulum is given by

$$\eta = \frac{16\pi ml}{a^4}\left(\frac{d_2^2 - d_1^2}{T_2^2 - T_1^2}\right) \; dyne/cm^2$$

Here m=mass of each cylinder, gm.

l = length of the wire, cm

a = radius of the wire, cm

$d_1 \& d_2$ *are distance of the cylinder center from chuck nut center*

$T_1 \& T_2$ *are time period of oscillation corresponding to distance* $d_1 \& d_2$

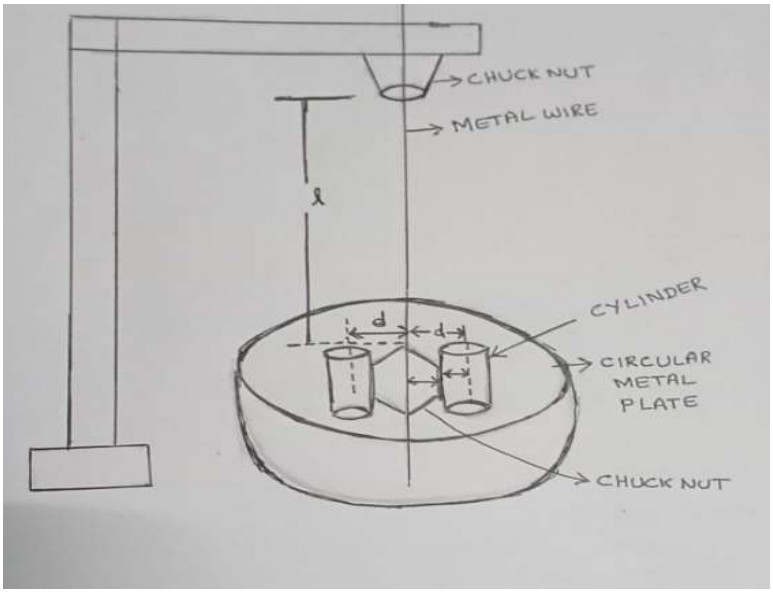


TABLE -1 FOR THE DETERMINATION OF RADIUS OF CYLINDER USING VERNIER CALIPERS.

S.No	M.S.R "a" cm	VC	VCxLC "b" cm	Radius=$\frac{a+b}{2}$ cm

TABLE-2 FOR THE DETERMINATION OF RADIUS OF CHUCK NUT USING VERNIER CALIPERS

S.No	M.S.R "a" cm	VC	VCxLC "b" cm	Radius=$\frac{a+b}{2}$ cm

TABLE-3 FORTHE DETERMINATION OF RADIUS OF WIRE USING SCREW GAUGE

Screw gauge error: ___+ve/___-Ve Correction ___-ve/___+ve LC=0.001cm

S.No	P.S.R "a" cm	H.S.R		b=nxLC cm	Diameter "a+b" Cm	Radius=$\frac{a+b}{2}$ Cm
		Observed	Corrected "n"			

TABLE -4 FOR THE DETERMINATION OF TIME PERIOD OF OSCILLATION

Length of the wire $l = - - - - - cm$

S.No	Distance of the cylinder center from chuck nut center (d) cm	Time taken for 10 oscillations			Time period(T)=t/10 sec	d^2 Cm^2	T^2 Sec^2
		Trail-1	Trail-2	Mean(t)			

GRAPH: A graph is drawn between d^2 values on X-axis and T^2 values on Y-axis, then the nature of the graph is as shown in Figure.



PRECAUTIONS:

l. The suspension wire should be well clamped, thin long and free from kinks.

2. The period of oscillations should be measured accurately since they occur in second power in the formula.

3. Radius of the wire should be measured very carefully since it occurs in fourth power.

3.NEWTON RINGS

AIM : To determine the radius of curvature of given plano - convex lens by forming Newton rings.

APPARATUS: Plano – convex lens, optically plane glass plate, Plane glass plate inclined at 45^0, sodium vapour lamp, travelling microscope, reading lens, black sheet.

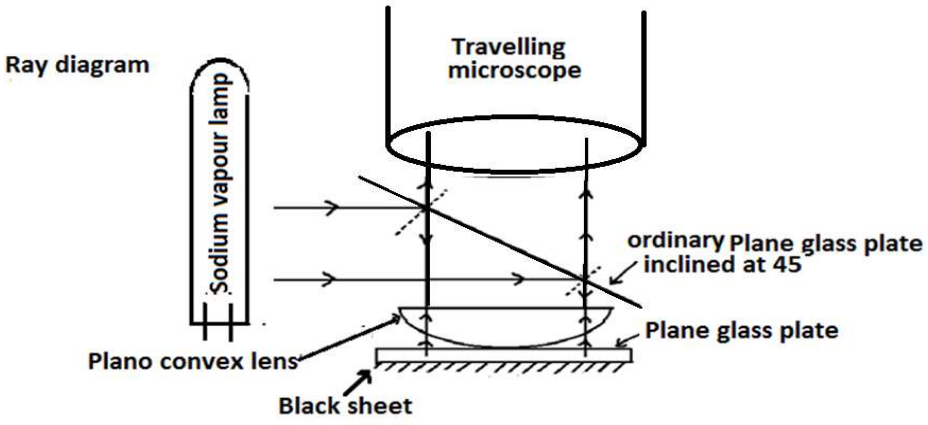
PRINCIPLE: This experiment is based on the principle of interference.

FORMULA: The expression for radius of curvature of a given plano-convex lens, in Newton rings is given by

$$R = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} cm$$

Here D_m & D_n are the diameters of m^{th} & n^{th} ring respectively.

λ= Wavelength of light source used.(Use λ= 5890 A°)



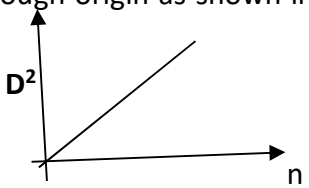
TABLULAR FORM FOR THE DETERMINATION OF DIAMETER OF A RING

S.No	Ring number " n "	Readings of travelling microscope						Diameter of the ring D = $R_L \sim R_R$ cm	D^2
		Left			Right				
		M.S.R " a "	VC x LC " b"	Total reading R_L= a+b	M.S.R " a "	VC x LC " b"	Total reading R_R= a+b		

GRAPH:

Plot a graph by taking ring number on X- axis and corresponding square of the diameter of the ring on Y- axis, we get a graph as a straight line passing through origin as shown in Fig. below.

" R " value can also be found from the graph, by taking the slope of the straight line



PRECAUTIONS:-

1) Glass plates and lens should be cleaned thoroughly.
2) In order to avoid any error due to back-lash of the screw in the travelling microscope, the micrometer screw should be moved only in one direction for the measurement of diameter of rings
3) Crosswire should be focused on a bright ring tangentially.
4) Do the calculation in cgs units only.

4.DETERMINATION OF WAVELENGTH OF LASER BY DIFFRACTION GRATING

AIM: To determine wavelength of LASER source by using plane transmission grating.

APPARATUS: Diode LASER, power supply, plane transmission diffraction grating, scale, screen, graph paper.

FORMULA: The condition for nth order diffraction principle maxima is given by

$$(e+d)sin\theta = n\lambda - - - - - (1)$$

Here (e+d) is width of each slit or grating element, "n" is order of diffraction.

where x_n *is the distance of* n^{th} *order from zeroth order*

The expression for wavelength of LASER source from the above expression is given by

$$\lambda = \left(\frac{e+d}{n}\right)\left[\frac{x_n}{\sqrt{x_n^2 + D^2}}\right] \text{Å}$$

"D" is distance between grating and screen

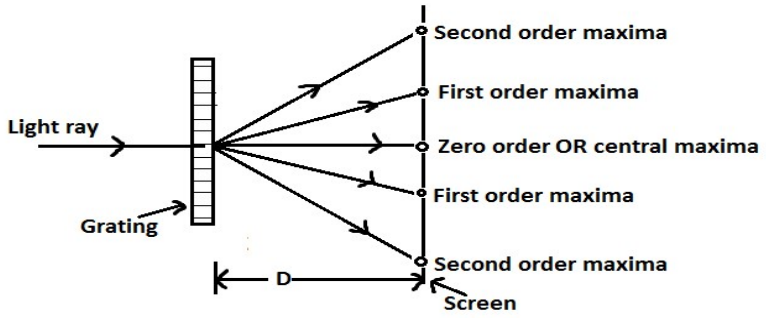


FIGURE 1

TABLE FORM

S.No	Distance between screen & grating (D)	Distance of n^{th} order from central maxima			$\lambda = \left(\frac{e+d}{n}\right)\left[\frac{x_n}{\sqrt{x_n^2+D^2}}\right]$ Å
		Left	Right	Mean(X_n)	

PRECAUTIONS

1. Clean the grating surface with soft cloth and do not touch the surface with fingers till the experiment is over.

2. Mark spots of various orders on graph paper with pencil at the center of that spot.

3. Do not see the LASER light with naked eye, because it cause loss of sensation of vision.

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5. SOLAR CELL

AIM: To study the characteristics of a photo voltaic cell (Solar cell) and to find Fill factor.

APPARATUS: Solar cell, d.c milli volt meter, d.c micro ammeter, variable resistance box, 100W Lamp, connecting wires.

PRINCIPLE: This experiment is based on the principle of photo voltaic effect. i.e. When light energy falls on to a open circuited P-N junction, electron- hole pairs are created, and they were separated by junction electric field. These separated charges accumulated on P and N regions and leading to create potential difference across the ends, called Photo – voltaic effect.

FORMULA: Fill factor of a solar cell is given by

$$\text{Fill Factor} = \frac{P_{Max}}{I_{sc}\,X\,V_{oc}} = \frac{V_m\ X\ I_m}{I_{sc}\,X\,V_{oc}}$$

Where I_{sc} = short circuited current (when resistance in the circuit is zero i.e. R=0)

V_{oc} = open circuited voltage (when resistance in the circuit is infinity i.e. R= ∞)

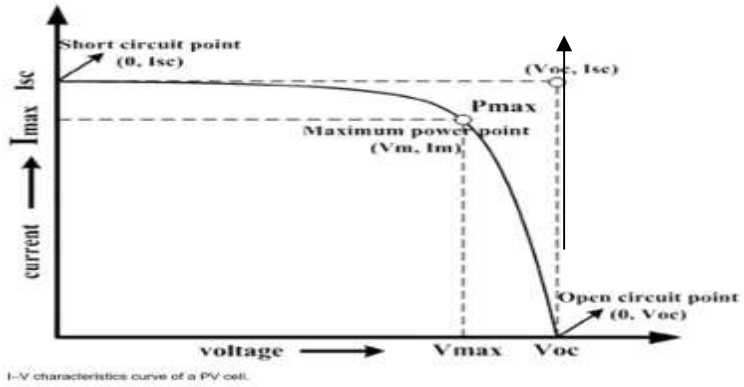
$\boldsymbol{I_{sc}\,X\,V_{oc}}$= is the ideal power or dummy power output, and $\boldsymbol{V_m\ X\ I_m}$ is actual maximum obtainable power

TABLE FORM FOR MEASUREMENT OF POWER

S.No	Resistance in ohms (R)	*Reading of voltmeter & ammeter*		Power =IxV watt *mW*
		Voltmeter mV	Ammeter mA	

GRAPH:

Draw a graph by taking voltage values on X-axis and corresponding current values on Y-axis, we get the following nature, as shown in Fig. Also draw two straight lines at V_{oc} and I_{sc}. The area spanned by I_{sc} x V_{oc} is the dummy power or ideal power produced from the circuit.



I-V characteristics curve of a PV cell.

PRECAUTIONS:

1. Expose the solar cell to sun light for few minutes, for attaining stable values of current and voltage
2. A resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

6.FIELD ALONG THE AXIS OF A CURRENT CARRYING CIRCULAR COIL

AIM : To determine the magnetic field along the axis of a current circular coil, using Stewart-Gees apparatus.

APPARATUS: Stewart-Gees apparatus, D.C. Power supply, magnetometer, commutator, rheostat, ammeter.

Working formula: The magnitude of the field B along with the axis of a coil is given by

$$B = \frac{\mu_0 n i\, a^2}{2(x^2 + a^2)^{3/2}}\ \ Tesla$$

Where n = number of turns in the coil.

a = radius of the coil

i = current in ampere flowing in the coil

x = distance of the point from the centre of the coil.

μ_0 = permeability of free space

According to tangent law, magnetic field along the axis of circular coil is given by

$$\boldsymbol{B = B_E Tan\theta}.$$

B_E = Horizontal component of earth's magnetic field

$\boldsymbol{\theta = Angle\ of\ deflection\ in\ magnetometer}$

CIRCUIT DIAGRAM

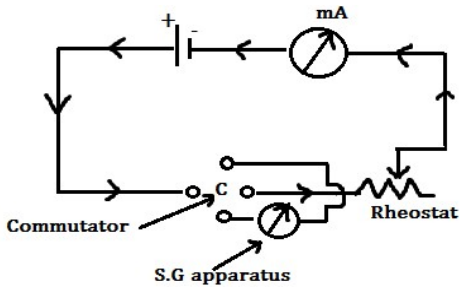


TABLE FORM FOR THE DETERMINATION OF 'B' VALUES

S.No	Distance of each point from center of the circular coil (cm) "x"	Deflections in magnetometer									θ=(Average of θ_E to θ_W) (deg)	Tan θ	B = B_H Tan θ Tesla	$B = \frac{\mu_0 n i a^2}{2(x^2+a^2)^{3/2}}$ Tesla
		East side of the coil (degrees)					West side of the coil (degrees)							
		Direct		Reverse		θ_E=Average of θ_1 to θ_4	Direct		Reverse		θ_W=Average of θ_5 to θ_8			
		θ_1	θ_2	θ_3	θ_4		θ_5	θ_6	θ_7	θ_8				

GRAPH: Plot graph taking "x" along X-axis, and Tanθ along Y- axis, and then we get a bell shaped graph as shown in Fig. below. The nature of the graph is symmetrical about Y- axis.

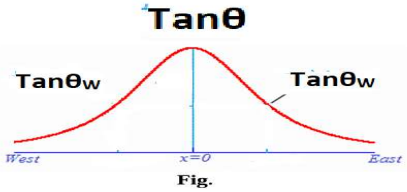


Fig.

PRECAUTIONS: -

1) The coil should be carefully adjusted in the magnetic meridian.
2) All the magnetic materials and current carrying conductors

should be at a considerable distance from the apparatus.
3) The current passed in the coil should be of such a value as to produce a deflection of nearly 50° -60°
5) Parallax should be removed while reading the position of the pointer. Both ends of the pointer should be read.

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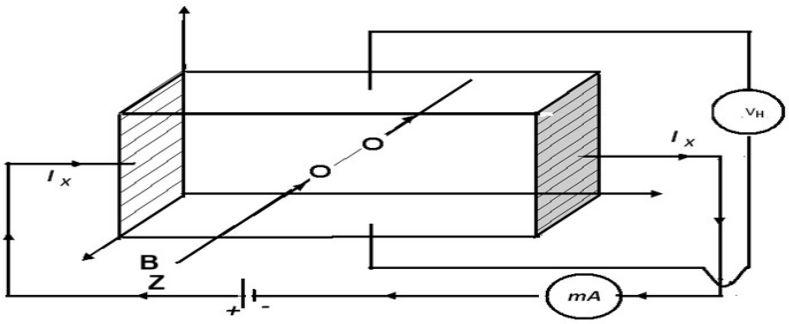
7. HALL EFFECT

Aim: To determine the hall coefficient (k_H), mobility of charge carriers(μ) and concentration of charge carriers(n) in a given material

Apparatus: Hall probe, Hall effect setup for measurement of current and voltage, electro-magnet, constant dc power supply to electro-magnet and Gauss meter.

Hall Effect: When magnetic field is applied perpendicular to a current carrying conductor, then a voltage is developed in a direction both perpendicular to charge flow and applied magnetic field direction ; is known as Hall effect. The developed voltage is known as Hall voltage(v_H).

CIRCUIT DIAGRAM



FORMULA:

1. Hall coefficient K_H is given by

$K_H = \left(\frac{V_H}{I_X}\right)\left(\frac{t}{B_Z}\right)\ \Omega - \frac{m^3}{Web}$ & it is measured from $V_H Verses\ I_x\ graph$ as

$$K_H = \frac{(slope\ of\ V_H Verses\ I_x\ graph)t}{B_Z}$$

$Here,\quad V_H = Hall\ voltage$

$t = thickness\ of\ the\ sample = 0.5mm = 0.5x10^{-3}$m

$B_Z = applied\ magnetic\ field\ in\ the\ z\ direction\ (B_Z = 0.25\ Tesla)$

2. **Concentration of charged carriers (n) =** $\frac{1}{K_H e}\ Per\ m^3$

Where "e" is the charge of electron = 1.6X10^{-19} c

3. Mobility of charge carriers (μ)= $K_H \sigma$ $m^2/volt-sec$

where σ = conductivity of sample = 1/ρ, ρ= resistivity of sample, given by

$\rho = \frac{RA}{l} = \frac{R(bt)}{l} = \text{Rt}\,\Omega - \text{m}$ $(since\ in\ our\ sample\ "l" = "b" = 5mm)$ $Resistance "R" = \frac{V_x}{I_x}$

Table – I:FOR THE MEASUREMENT OF RESISTIVITY

S.No.	Current I_x (mA)	Voltage V_x (mV)

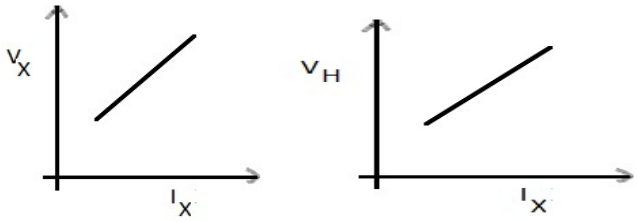
Table – II: FOR THE MEASUREMENT OF HALL VOLTAGE.

Model graph:

S.No	Current I_x	Transverse voltage (OR) HALL VOLTAGE		True Transverse voltage (OR) True Hall voltage V_y= b-a (mv)
		With out magnetic field 'a' (mV)	With magnetic field 'b' (mV)	

(1) Plot the graph between I_x on x-axis, V_x on y-axis, we get a straight line.

(2) Plot the graph between I_x on x-axis, V_H on y-axis we get a straight line.



PRECAUTIONS:

1 Increase slowly the current through electromagnet from power supply (max up to 2A).

2 Before to switch off power supply, reduce current to zero and the switch off.

3 Keep the probe in the Gauss meter at the center of pole pieces and rotate at till it shows maximum reading for the measurement of magnetic field.

---

8. LCR SERIES RESONANCE CIRCUIT

AIM: To determine resonating frequency and quality factor in the LCR series circuit.

APPARATUS: A signal generator, inductor, capacitor, ammeter, resistors, AC milli ammeter.

FORMULA: When L, C & R are connected in series, the resonance frequency f_r is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

Here "L" is self-inductance of inductor measured in Henrys

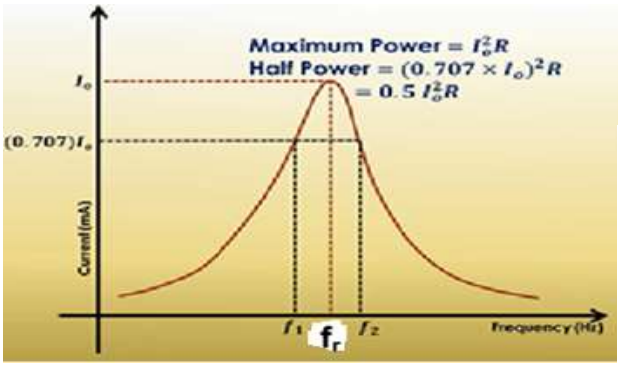
"C" is capacitance of capacitor measured in Farads

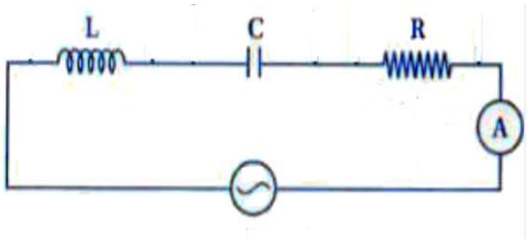
The **quality factor (Q-factor)** in an LCR circuit measures the circuit's efficiency and selectivity at resonance, directly impacting how sharply it can distinguish a specific frequency and how effectively it stores energy versus dissipates energy. It is measured with the formula below

$$\mathbf{Q}=\frac{\omega_0 L}{R}=\frac{2\pi f_r L}{R}=\frac{1}{R}\sqrt{\frac{L}{C}}$$ **(since** $f_r = \frac{1}{2\pi\sqrt{LC}}$ **)** It is dimensionless quantity

It is also measured from graph as $\mathbf{Q}=\frac{f_r}{\Delta f} = \frac{f_r}{f_2 - f_1}$

Here Δf is band width=difference between frequencies where the power falls to half of its maximum value at resonance.





LCR SERIES CIRCUIT

TABLE FORM

L = _____ mH C = _____ μF.

S.No	Applied frequency f Hz	Voltage across resistor (R)		
		R=	R=	R=

RESULT :

Resonance frequency for series LCR circuit =_____Hz

Quality factor measured from observation_____, from graph_____

9. FORBIDEN ENERGY GAP OF SEMICONDUCTOR

AIM: To determine the energy gap of material of PN junction diode by connecting in reverse bias

Apparatus : Electric heater Transformer oil Ge/Si diode DC Power supply, micro ammeter, voltmeter, thermometer & retard stand.

FORMULA: When PN-Junction diode is reverse biased, the expression for reverse saturation current(Is) is given by

$$I_s = A\left(e^{-E_G/\eta kT}\right) \quad \text{----------(1)}$$

Here Eg is energy gap of the material,

"**η**" is a constant depends on material,

"**η**" =1 for Germanium diode and **η**=2 for silicon diode,

In this experiment, the PN junction is made from germanium diode, hence the expression for reverse saturation current is given by

$$I_s = A\left(e^{-E_G/kT}\right) \quad \text{----------(2)}$$

Apply ting logarithm on both sides of the above equation, we get,

$$log_e I_s = log_e A - \left[\frac{E_G}{K}\right]\frac{1}{T}$$

$$log_{10} I_s = \left[\frac{-E_G}{(2.303)K}\right]\frac{1}{T} + log_{10} A \quad \left[\begin{matrix} since\ log_e I_s = 2.303\ log_{10} I_s\ and \\ log_e A = 2.303 log_{10} A \end{matrix}\right]$$

When a graph is drawn between $\boldsymbol{log_{10} I_s}$ on y-axis and $\frac{1}{T}$ **x10^3** on x-axis we get a straight line having a negative slope as show in Fig. The slope of the graph is given by

$$m = \frac{E_G}{(2.303)K}$$

Energy gap of the semiconductor material can be determined by substituting the Boltzmann constant "k"=8.62x10^{-5} eV/K in the above expression for slope, we get

$$\boldsymbol{E_G = (slope)\ x\ (2.303)k \quad eV}$$

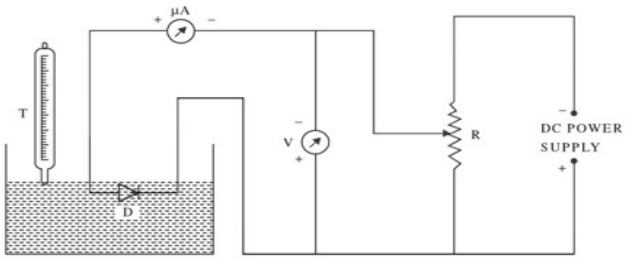
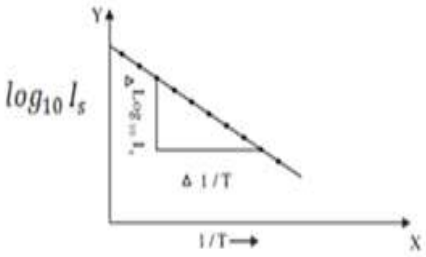


TABLE FOR OBSERVATIONS

S.NO.	CURRENT I_s IN μA	TEMPERATURE IN ^{O}C	TEMPERATURE IN KELVIN (T)	$\frac{1}{T}$	$log_{10} I_s$

MODEL GRAPH: A graph is drawn between $log_{10} I_s$ on y-axis and $\frac{1}{T}$ x10^3 on x-axis we get a straight line as show in Fig. and measure the slope of the graph.



Result: Energy gap of the given semiconductor material_____eV

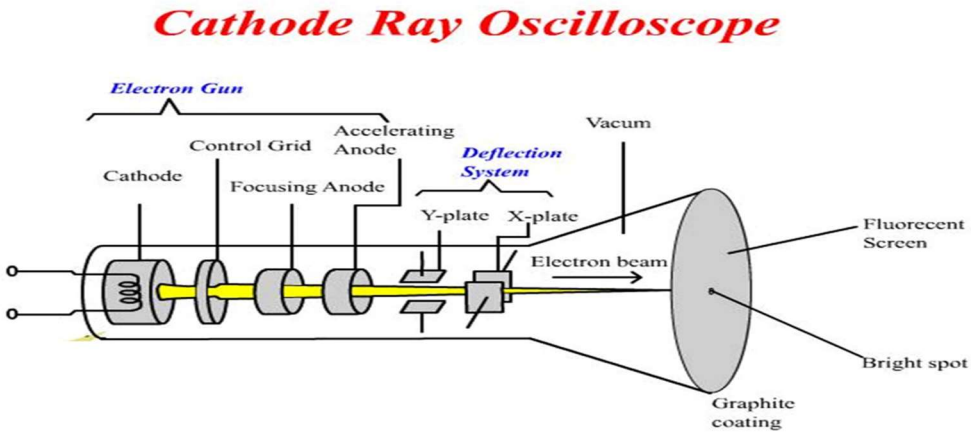
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10. CATHODE RAY OSCILLOSCOPE

AIM:- To study the different waveforms, to measure and compare voltages and the frequency of A.C.

APPARATUS:- A C.R.O and a signal generator.

BLOCK DIAGRAM OF CRO: The various



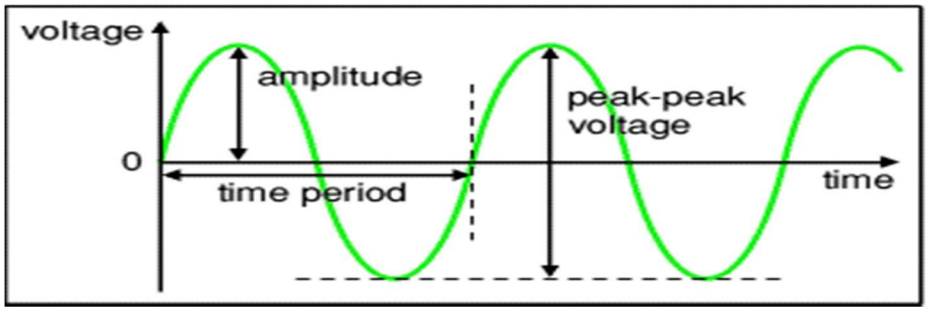


TABLE - I FOR VOLTAGE COMPARISION

S.NO	APPLIED VOLTAGE "A" VOLTS	HEIGHT OF THE SIGNAL "X"	VOLT/DIV "Y"	OBSERVED VOLTAGE "B"=XY (VOLTS)	DIFFERENCE IN VOLTAGE A≈B

TABLE - 2 FOR FREQUENCY COMPARISION

S.NO	APPLIED FREQUENCY "A" Hz	WIDTH OF THE SIGNAL "X"	TIME/DIV "Y"	TIME PERIOD T=XY Sec	OBSERVED FREQUENCY B=1/T Hz	DIFFERENCE IN FREQUENCY A≈B

PRECAUTIONS :-

1.The continuity of the connecting wires should be tested first.

2.The frequency of the signal generator should be varied such that steady wave form is formed.

3.An oscilloscope should be handled gently to protect its fragile