MANIPAL INSTITUTE OF TECHNOLOGY
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DEPARTMENT OF PHYSICS

I/II SEMESTER B.TECH

ENGINEERING PHYSICS

LAB MANUAL [PHY 1061]

(May-July, 2021)

CONTENTS

Ex. No.: 1 Date:..............................

ENERGY BAND GAP

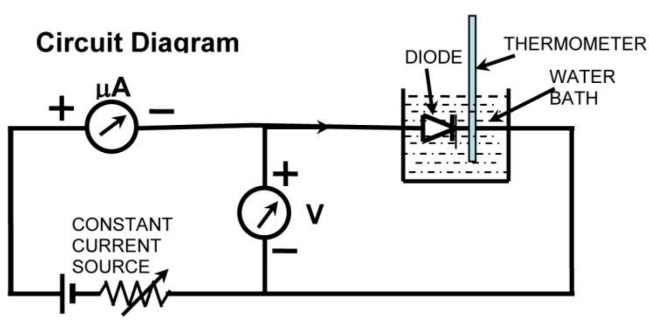
Aim: To determine the forbidden energy gap of semi-conductor.

Apparatus: A semiconductor diode, constant current source, current meter, voltmeter, water bath, thermometer etc.

Principle: Forbidden energy gap E_g of a material is the energy difference between the upper limit of its valance band and the lower limit of its conduction band. The semi conductor used is in the form of a p-n junction diode. For a small forward current (I < 0.1 mA), the voltage V across the diode varies approximately with the absolute temperature T as

$$eV = E_g - \eta kT$$

where E_g is the energy gap of the semiconductor, η is a constant that depends on the type of the semiconductor, $e = 1.6 \times 10^{-19}$C is the electronic charge and $k = 1.38\times10^{-23}$ J/K is the Boltzmann constant.



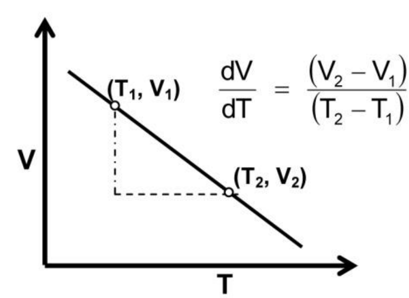


Fig: Experimental set up and graph of voltage versus temperature.

A graph of V versus T is a straight line with a V-intercept = $\frac{E_g}{e}$ at T = 0 K. Thus the energy gap of the semiconductor can be determined by calculating the V- intercept.

Procedure: Construct the electrical circuit as shown in the figure. Connect the diode under forward bias and pass a constant current (I_F < 0.1 mA) through the diode. Note down the junction voltage at room temperature. Suspend the diode along with a thermometer in a hot water bath at about 90° C taking care to see that the bulb of the thermometer is at the same level as the diode. As the water bath cools down, note down the voltage across the diode for different temperatures. Draw a graph with the temperature in Kelvin on the X-axis and voltage across the diode along the Y-axis. Find the V-intercept of the line at zero Kelvin using the slope of the straight line obtained and calculate the energy gap of the semiconductor.

Observations and Calculations:

The p-n junction diode used: ....

Constant forward current through the diode, I_F = ... mA

To find the voltage across the junction at various temperatures :

Temperature in °C	**Temperature in K (T)**	**Junction Voltage (V)**

From the graph, Slope $\frac{dV}{dT} =$ ....

$$E_g = e\left[V_1 - \left(\frac{dV}{dT}\right)T_1\right] \text{ joule}$$

$$E_g = V_1 - (slope \times T_1) \text{ electron-volt}$$

= ....

= .... eV

Result: The energy gap of the given semiconductor, E_g = ... eV

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Review Questions:

1. Define energy band gap of a soild.
2. Differentiate metal, semiconductor and insulator based on band theory of solids.
3. Why the conductivity of a semiconductor increases with increase in temperature ?

Reference Book: Solid State Physics by Dekker, 1957, Macmillan, India Ltd.

Ex. No. : 2 Date :.......................

RESISTIVITY OF SEMICONDUCTOR USING FOUR PROBE METHOD

Aim: To determine the resistivity of the given semiconductor by four probe method.

Apparatus: Constant current source, Four probes with connecting wires, Semiconductor sample in the form of a square plate, digital milliammeter, digital millivoltmeter.

Theory: The electric resistance (R) of a material is given by $R = V/I$ where V is electrical potential difference across the material and I is the current through the material. The resistance depends on the dimension of the material. For a wire $R = \rho L/A$, where L is the length of the area, A is the cross sectional area of the wire and ρ is the electrical resistivity of the material of the wire. Thus for a wire, the resistivity,

$$\rho = \frac{R \times A}{L}$$

When two probes are used for measurement of voltage and current, and hence for the calculation of resistance in the case of a semiconductor, the probe resistance, the contact resistance, the spreading resistance, and the sheet resistance due to the semiconductor will come into effect. Using four probes one can eliminate the probe resistance, contact resistance and the spread resistance in the measurement.

In the four probe method the four metal probes are equidistant, the current is passed through the outer probes and the voltage is measured across the inner probes. The resistivity measured using the four probes may vary with the geometry (thickness and shape) of the semiconductor sample and placement of the probes on the surface of the sample. It may also vary with the probe gap, nature of the surface of the sample, the size of the sample.

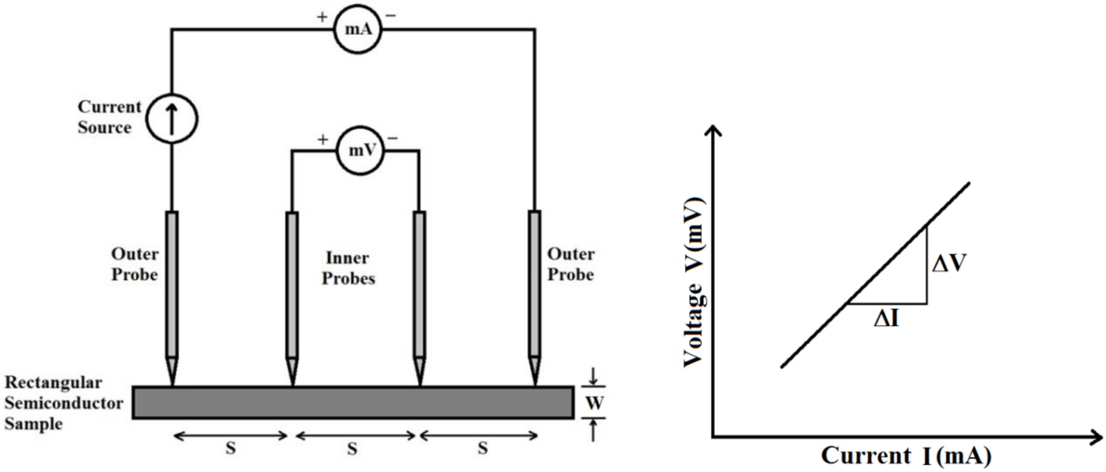

Fig: Experimental setup and graph of voltage versus current.

Mathematical calculations show that the resistivity of a semi-infinite sample is given by

$$\rho_0 = \frac{V}{I} \times 2\pi S$$

where I is the current through the outer probes, V is the voltage across the inner probes, S is the distance between the probes and $2\pi S$ is the geometric factor of the semi-infinite sample.

For a finite rectangular sample of thickness W, a dimension correction function $f\,(W/S)$ is introduced in the resistivity expression as,

$$\rho = \frac{\rho_0}{f(W/S)}$$

i.e.,

$$\rho = \frac{2\pi S}{f(W/S)} \times \frac{V}{I}$$

According to the standard data chart, for a germanium crystal of thickness 0.5mm (W) and distance between the probes 2mm (S), the value of the dimension correction function $f\,(W/S)$ is 5.85. In the experiment the value of the electrical resistance (V/I) of the sample can be obtained by calculating the slope of straight line in the graph of voltage versus current.

Hence the resistivity of the germanium crystal is given by,

$$\rho = \frac{2\pi S}{5.85} \times slope$$

Procedure:

- Note the values of the sample thickness (*W*) and probe gap (*S*). Place the sample under the four probes with probes coming at the center and along the length of the rectangle.
- Build up the circuit with the four probes, current source, DVM (digital milli voltmeter), DCM (Digital milli ammeter) and the semiconductor sample as shown in the circuit diagram.
- Pass a small current (*I*) about 0.2 mA through the outer probes and note the value of the voltage (*V*) across the inner probes.
- Repeat the procedure by increasing the current value in steps of 0.2 mA.
- Plot a graph of V versus I and calculate the slope $\Delta V/\Delta I$ of the straight line obtained.
- Calculate the resistivity of the germanium sample using the equation,

$$\rho = \frac{2\pi S}{5.85} \times slope$$

Observation and Calculations:

Material of the semiconductor sample : Germanium crystal

Distance between the probes, $S = 2 \times 10^{-3}$ m

Sample thickness, $W = 0.5 \times 10^{-3}$ m

Dimension correction function, $f(W/S) = 5.85$

Current ***I*** **(mA)**	**Voltage** ***V*** **(mV)**

From the graph, *slope* = $\frac{\Delta V}{\Delta I}$ =...

Resistivity of the germanium crystal,

$$\rho = \frac{2\pi S}{f(W/S)} \times slope$$

$$= \frac{2\pi S}{5.85} \times slope$$

= ....

= ....Ωm

Result:

Resistivity of the given semiconductor, $\rho =$ ....Ωm

*****

Review Questions:

1. Define resistivity of a material.
2. What is the relation between resistance and resistivity of a material ?
3. What are the advantages of four probe method over two probe method ?

Reference Book: W.R. Runyan, Semiconductor Measurements and Instrumentation; McGraw – Hill Book Company (1975)

Ex. No. : 3 Date :......................

FERMI ENERGY OF A METAL

Aim: To determine the Fermi energy of Copper.

Apparatus: Copper wire, DC regulated power supply, digital milliammeter, digital millivoltmeter, water bath, thermometer.

Theory: The *Fermi energy* (E_F) is the energy of the highest energy level occupied by an electron in a metal at zero kelvin temperature. The average speed of the electrons at Fermi level is *Fermi speed* (v_F).

$$E_F = \frac{1}{2} m v_F^2 \qquad (1)$$

where m is the mass of electron. *Fermi temperature* (T_F) is related to the Fermi energy by the relation,

$$E_F = kT_F \qquad (2)$$

where k is Boltzmann constant. For a monovalent metal the number of free electrons (n) in unit volume of the metal is equal to the number of atoms (N) per unit volume. N is related to the molar mass (M) Avogadro number (N_A) and density (ρ) of the metal by the relation,

$$n = \frac{N_A \times \rho}{M}$$

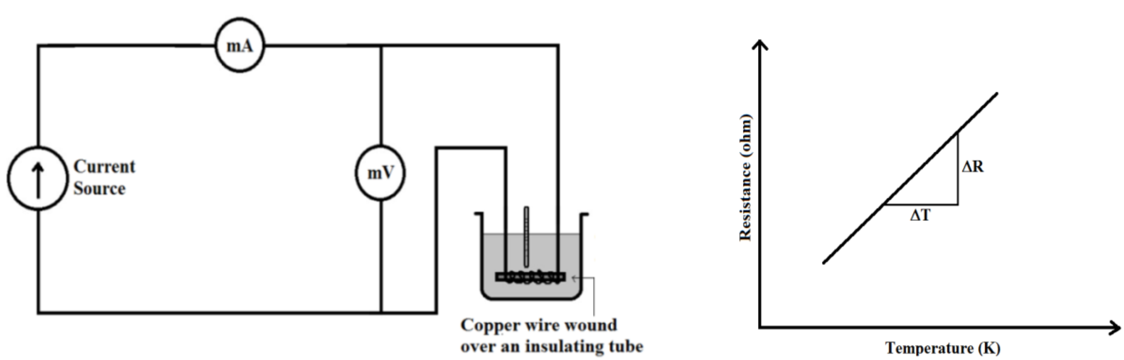

Fig: Experimental set up and graph of resistance versus temperature

The electrical conductivity (σ) of the metal is given by the relation,

$$\sigma = \frac{L}{R \times A}$$

where L is the length of the metal wire, R is its resistance of the wire, $A = \pi r^2$ is the area of cross-section of the wire, r is the radius of cross section of the wire.

The relaxation time (τ) of the free electrons is given by the relation,

$$\tau = \frac{\sigma \times m}{n \times e^2}$$

where e is electron charge. The mean free path (λ_F) of the free electrons at Fermi level is given by the relation,

$$\lambda_F = v_F \times \tau$$

Hence the expression for *Fermi energy* in terms of these quantities, take the form,

$$E_F = \frac{\pi^2 \times n^2 \times e^4 \times \lambda_F^2 \times R^2 \times r^4}{2 \times m \times L^2} \tag{3}$$

Since the mean free path is inversely proportional to the temperature, $\lambda_F \times T = B$, a constant. Substituting this in equation (3), we get

$$E_F = \left[\frac{\pi^2 \times n^2 \times e^4 \times B^2 \times r^4}{2 \times m \times L^2}\right] \left[\frac{R^2}{T^2}\right] \tag{4}$$

In the experiment the resistance (R) is measured at various temperatures (T) and a graph is drawn to find slope ($\Delta R/\Delta T$). Now in equation (4) R/T is replaced by slope to get the Fermi energy:

$$E_F = \left[\frac{\pi^2 \times n^2 \times e^4 \times B^2 \times r^4}{2 \times m \times L^2}\right] [slope]^2 \tag{5}$$

Equation (5) can be further simplified by substituting the suitable values of different parameters namely,

Density of Copper, $\rho = 8930$ kg/m^3

Avogadro number, $N_A = 6.023 \times 10^{23}$ /mol

Molar Mass of Copper, $M = 63.54 \times 10^{-3}$ kg/mol

Free electron density, $n = \frac{N_A \times \rho}{M}$ = 8.464×10^{28} /m^3

Electron charge, $e = 1.602 \times 10^{-19}$ C

Electron mass, $m = 9.1 \times 10^{-31}$ kg

Mean free path of electron at $T = 300$K, $\lambda_F = 2.7 \times 10^{-8}$ m

Hence, constant $B = \lambda_F \times T = 8.1 \times 10^{-6}$ m.K

Thus, equation (5) reduces to

$$E_F = 1.679 \times 10^3 \times \frac{r^4}{L^2} \times [slope]^2 \tag{6}$$

Procedure:

- Take a long copper wire of known length (L) and radius of cross section (r). Construct the electrical circuit using this long copper as shown in the figure.
- Pass a constant current (I) through the Copper wire at room temperature using a constant current source and note down the voltage (V) across copper wire. Meantime note down the room temperature (T) using thermometer. Calculate the resistance ($R = V/I$) at this temperature.
- The copper wire and a thermometer are housed in a test tube and this tube is then suspended in a hot water bath at about 100°C. The temperature of the copper wire inside test tube may rise up to maximum 75°C due to the air medium separating it from water bath.
- As the water bath cools down, the voltage across the copper wire and hence its resistance values are noted at various temperatures in steps of 3°C.
- A graph is drawn with the temperature in Kelvin on the X-axis and resistance of the copper wire along the Y-axis. Calculate the slope ($\Delta R/\Delta T$) of straight line obtained.
- Calculate the *Fermi energy* of copper using the equation (6). Also calculate the *Fermi speed* of the conduction electrons using equation (1) and *Fermi temperature* using equation (2).

Observation and Calculations:

Length of copper wire, L = ... m

Radius of cross section of copper wire, r = ... m

Current passed through the copper coil, I = ... mA

Temperature		Voltage V (mV)	Resistance R = V/I (Ω)
t (°C)	T (K)		

From the graph, *Slope* = $\frac{\Delta R}{\Delta T}$ = ... Ω/K

Fermi energy of Copper, $E_F = 1.679 \times 10^3 \times \frac{r^4}{L^2} \times [slope]^2$

= ....

= ………………………………..…………… J

= ………………………………… eV

Boltzmann Constant, $k = 1.38 \times 10^{-23}$ J/K

Fermi temperature, $T_F = \frac{E_F}{k}$ =…………………………………= ……………………………………K

Electron mass, $m = 9.1 \times 10^{-31}$ kg

Fermi speed, $v_F = \sqrt{\frac{2E_F}{m}}$ = ……………………..………………… = ………………..…..……… m/s

Result:

Fermi Energy (E_F) (eV)		**Fermi Temperature (T_F) (K)**		**Fermi Speed (v_F) (m/s)**	
Observed	**Theoretical**	**Observed**	**Theoretical**	**Observed**	**Theoretical**
	7.0		8.12×10^4		1.57×10^6

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Review Questions:

1. Define Fermi energy and Fermi temperature.
2. What do you mean by Fermi speed ?
3. Why the resistance of the metal increases with increase in temperature ?
4. Explain the probability of occupation of electron in the energy states of the metal as the temperature increases from zero Kelvin.

Reference Book : Serway & Jewett; Physics for Scientists and Engineers with Modern Physics, Vol 2; 6e (1982), Thomson-Brooks/Cole

Ex. No.: 4 Date:..............................

PHOTOELECTRIC EFFECT

Aim: To determine the Planck's constant and the work function of the material of the photo cathode in the given photo-emissive cell.

Apparatus: Photo-emissive cell, a white light source, optical filters, a micro-ammeter, a voltmeter, connecting wires.

Principle: When light of a particular frequency falls on a photo-cathode, photo electrons are ejected. The kinetic energy (K_{max}) of the most energetic photo electron depends on the frequency (f) of the incident light. These electrons can be retarded by the application of a retarding potential and the electrons can be stopped completely by increasing the retarding potential to a value called stopping potential (V_o). Then no current (I_p) flows in the external circuit.

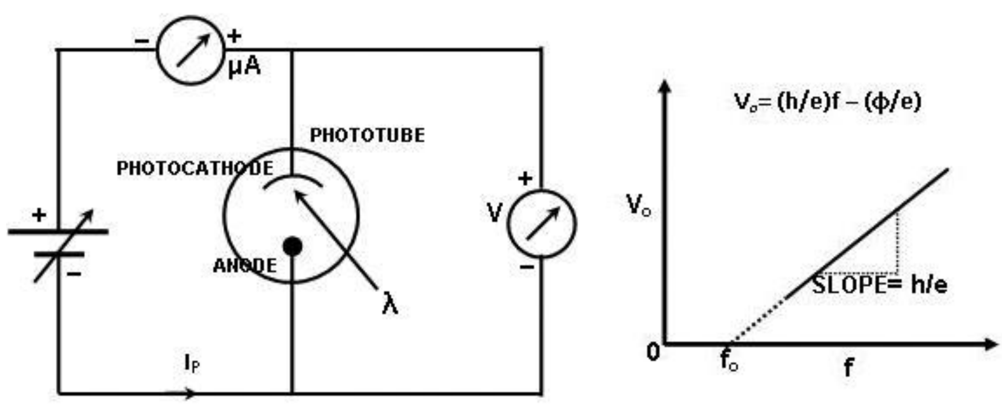

Fig: Circuit Diagram and variation of stopping potential with frequency.

In the experiment the stopping potentials are measured for lights of different frequencies. White light source and optical filters are used to get the light of a particular frequency. Einstein's photo electric equation is $K_{max} = hf - hf_o$, where h is the Plank's constant and f_o, is the threshold frequency. In the experiment $K_{max} = eV_o$ where e is the electronic charge. Hence the equation takes the form $eV_o = hf - hf_o$. A plot of V_o versus f gives a straight line graph with a slope equal to h/e and f-intercept f_o. The work function of the photo-cathode is given by $\phi = hf_o$.

Procedure: Build up the circuit as shown in the circuit diagram. Place an optical filter in the path of the light from a white light source. Note down the wavelength of the light from the filter and calculate the frequency. Illuminate the photo cathode using this light. Apply a retarding potential and increase its value so as to make the photo-electric current zero. Note down this stopping potential value. Similarly find the stopping potentials for lights of different frequencies using other filters. Draw a straight line graph of stopping potential versus frequency of the light. Find the slope and calculate the Planck's constant. Also, find the threshold frequency and calculate the work function of the photo cathode.

Observations and calculations:

To find the stopping potential for lights of different frequencies:

Optical filter		**Frequency** $f = \frac{3\times10^8}{\lambda}$ **(Hz)**	**Stopping potential** V_0 **(Volt)**
Colour	**Wavelength** λ **(m)**		
Red			
Yellow - I			
Yellow - II			
Green			
Blue			

From the graph, $slope$ = ……………………

$\therefore$ Planck's constant, $h = slope \times e$

$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 1.6 \times 10^{-19}$

$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ Js

From the graph, *threshold frequency* f_o = ………………………… Hz

$$\therefore \text{ Work function, } \phi = h\,f_o = \frac{(6.62\times10^{-34}\ \text{Js})\ (\qquad\qquad\qquad\qquad \text{Hz})}{(1.6\times10^{-19}\ \text{J/eV})}$$

$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots$ eV

Result:

Planck's constant, h = ………………………………………Js

Work function of the photo-cathode in the photo-emissive cell, ϕ = ……………………… eV

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Review Questions:

1. What is photoelectric effect?
2. What is work function of the metal?
3. What is the significance of threshold frequency?
4. Whether the kinetic energy of the emitted photo electron depends upon the intensity of the incident electromagnetic radiation?

Reference Book: Physics, Vol 2, 6 ed, by Serway & Jewett, 2004, Thomson Brooks / Cole

Ex. No.: 5 Date:...............................

HALL EFFECT

Aim: To determine Hall coefficient of a given semiconductor and hence its charge carrier density.

Apparatus: Electromagnet, Hall probe, variable DC power supply, milliammeter, millivoltmeter.

Principle: Consider a semiconductor (assumed to be n-type) in the form of a rectangular strip of width ***w*,** thickness *t* and electron density *n*. Let a current ***I*** flow along its length in X direction and a transverse magnetic field ***B*** be applied across its thickness **t** along the Y direction.

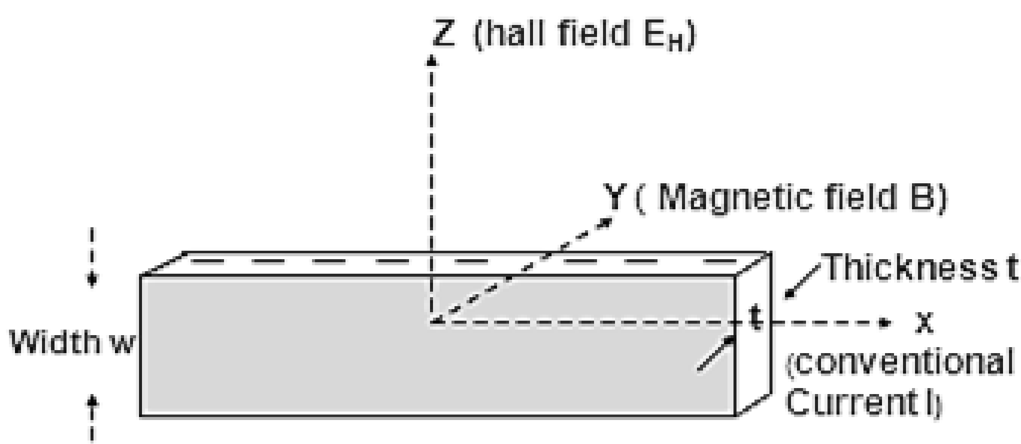

Fig : Hall Effect in *n*-type semiconductor

The moving electrons experience a force F_M due to the magnetic field. Due to F_M, the electrons tend to move in the Z direction leaving behind the positive charges.

$$F_M = e\, v_D\, B$$

where, v_D is the drift speed of the electrons and e is the charge on the electron.

This separation of charges results in an electric field E_H across the widthof the specimen (in Z direction). E_H exerts a force on the electrons given by

$$F_E = - e E_H$$

Under equilibrium conditions $e E_H = e v_D B$ $\therefore$ $E_H = v_D B$

We have $E_H = \frac{V_H}{w}$ and $v_D = \frac{I}{n e w t}$

Substituting these values, we get

$$V_H = \frac{\mathrm{I} B}{n e t} \quad \text{or} \quad V_H = \frac{R_H \mathrm{I} B}{t}$$

Where, the quantity $\frac{1}{n e} = R_H$ is called the Hall coefficient of the specimen.

$$\therefore R_H = \left(\frac{V_H}{B}\right)\left(\frac{t}{\mathrm{I}}\right)$$

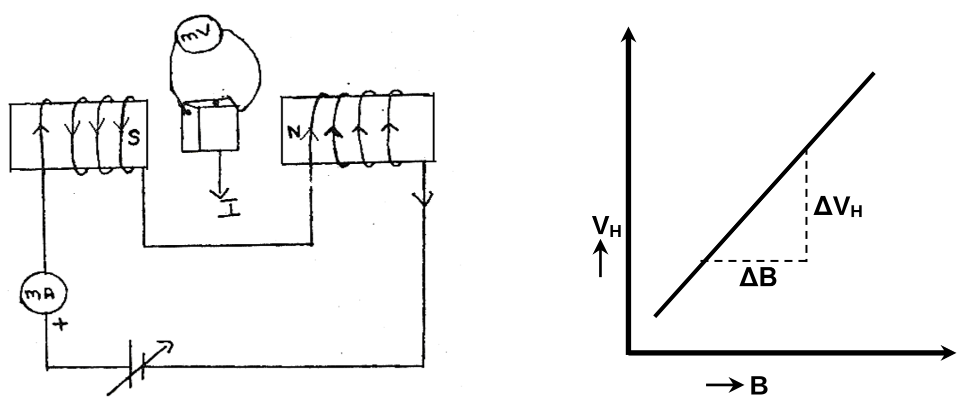

Fig: Experimental set up and graph of Hall voltage versus magnetic induction.

Procedure:

- Initially adjust the millivoltmeter to read zero hall voltage when the hall probe is **not** in the magnetic field.
- Adjust the distance between the pole pieces of the electromagnet to a prescribed value of 10 mm.

- Pass a current I (< 80 mA) through the hall probe.
- Introduce the probe midway between the pole pieces and orient it to have the hall voltage maximum.
- Vary the current through the electromagnet (in the given range 100-500mA) and note down the corresponding values of the Hall voltage V_H.
- Read the values of the magnetic induction B corresponding to these magnet currents from the chart provided.
- Draw a graph of V_H versus B.
- Find the slope of the straight line obtained. Calculate R_H and n.

Observations and Calculations:

Material of the Hall specimen : Indium Arsenide

Thickness of the Specimen : t =........................ mm = ... m

Current in the Probe : I =.........................mA = ... A

Charge on the electron : $e = 1.6 \times 10^{-19}$ C

Magnet Current (mA)	Magnetic Induction, B (Tesla)	Hall Voltage, V_H (mV)

From the graph, slope of the straight line = $\dfrac{\Delta V_H}{\Delta B}$ = ... volt/tesla

Hall coefficient of the specimen,

$$R_H = \left(\frac{t}{I}\right)(slope) = \left(\frac{\qquad\qquad}{\qquad\qquad}\right)(\qquad\qquad\qquad)$$

$$= \text{.......................................} \; m^3 / C$$

Number of charge carriers per unit volume of the specimen

$$n = \left(\frac{1}{e\,R_H}\right) = \frac{1}{(\qquad\qquad)(\qquad\qquad)} = \text{.......................................} \; /m^3$$

Result:

Hall coefficient of the given semiconductor, R_H =...m^3/C

Charge carrier density of the given semiconductor, n =......................................$/m^3$

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Review Questions:

1. Explain Hall Effect.
2. What are the two forces acting on the electron in Hall Effect setup?
3. What do you mean by charge carrier density of a material ?
4. What are the applications of Hall Effect ?

Reference Book: Physics, Vol 2, 6 ed, by Serway & Jewett, 2004, Thomson Brooks / Cole

Ex. No.: 6 Date:..............................

SERIES AND PARALLEL RESONANCES

Aim: To study the frequency response of the series and parallel resonance-circuits and to determine the inductance of the given inductor, and the quality factor of the circuit.

Apparatus: Audio frequency oscillator, wide band AC milliammeter, inductor, capacitor, resistor, connecting wires.

Theory: In a dc-circuit, resistance is the only quantity that opposes the current flow. But in ac-circuits, not only resistance but other circuit properties such as inductance and capacitance also oppose the flow of a c current. Inductance is that property of an electrical circuit that tends to oppose any change of current through it. Inductance has no effect on steady state direct current. In its simple form it is a coiled conductor.

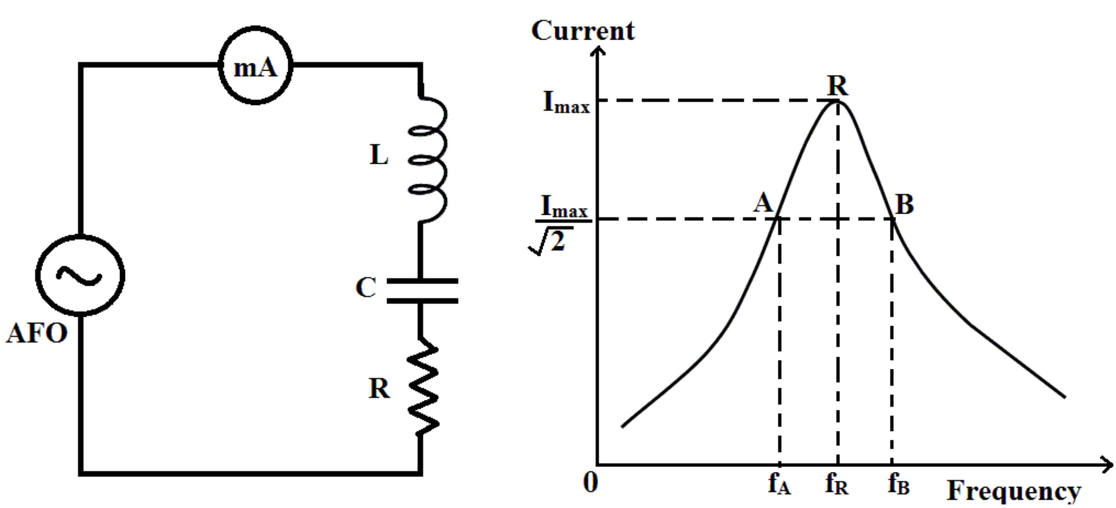

Fig: Series LCR circuit connection and its resonance curve.

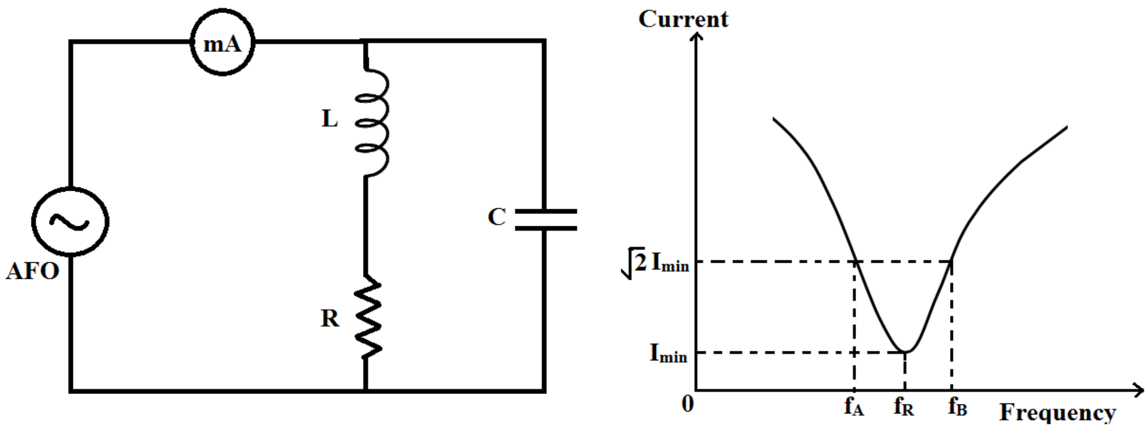

Fig: Parallel LCR circuit connection and its resonance curve.

In ac-circuits, since current is always changing, inductance is always opposing that change. The opposition is measured by a quantity called inductive reactance, which dependence both on frequency of the current and inductance of coil ($X_L = 2\pi fL$). In an inductor voltage always leads current by 90°. As against inductor, a capacitor blocks dc but allows ac to pass through. The opposition offered by a capacitor to an ac is measured by a quantity called capacitive reactance which depends inversely on both frequency of the current and capacitance of the capacitor ($X_C = 1/2\pi fC$). In a capacitor the current is leading the voltage by 90°. In a circuit containing resistance (R), inductance (L) and capacitance (C) in series, the impedance is given by $Z = \sqrt{R^2 + (X_L - X_C)^2}$ the effective reactance is inductive or capacitive depending on whether $X_L > X_C$ or $X_L < X_C$. At a certain frequency both reactances become equal and this frequency is called "resonance frequency (f_R)" i.e. at f_R, $X_L = X_C$ and hence $V_L = V_C \rightarrow 2\pi f_R L = 1/(2\pi f_R C)$ or $L = 1/(4\pi^2 f_R^2 C)$ or $f_R = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$. When $X_L = X_C$ at resonance frequency, the impedance is minimum and is equal to resistance, i.e., $Z = R$. Hence current in the circuit under these conditions is given by $I = V/R$.

In series LCR circuit, since $\cos\theta = R/Z = 1$, $\theta = 0$, i.e., both current and voltage are in phase. Such a circuit is also called *acceptor circuit*.

The ratio of voltage across inductance or across capacitor to the voltage across the resistance or applied voltage at resonance is called *Q-factor* or *voltage magnification factor* of the circuit:

$$Q = \frac{V_L}{V_R} = \frac{IX_L}{IR} = 2\pi\, f_R \left(\frac{L}{R}\right) = 2\pi . \frac{1}{2\pi}\left(\sqrt{\frac{1}{LC}}\right) . \frac{L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

When L and C are in parallel branches, at resonance frequency does not allow the flow of current and works as a prefect choke for ac. Such a circuit is called *rejecter circuit*. LCR circuits are used in signal communication.

Procedure:

Series Resonance: Build the the series resonance circuit as shown in the circuit diagram using an audio frequency oscillator, capacity of known capacitance C, resistor of known resistance R and an inductor of unknown inductance L. Note the values of the alternating current for different values of the frequency of ac.

Plot the points on a graph sheet and draw the series resonance curve. Find the resonant frequency (f_R), the resonant alternating current I_{MAX} from the graph. Corresponding to the alternating current $\frac{I_{MAX}}{\sqrt{2}}$, find the frequencies f_A and f_B from the graph, and calculate the band with ($\Delta f = f_B - f_A$).

Calculate the experimental value of the quality factor ($Q = f_R/\Delta f$). Evaluate the unknown inductance [$L = 1/(4\pi^2 f^2_R C)$]. Calculate the theoretical value of the quality factor: $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

Parallel Resonance: Build up the parallel resonance circuit as shown in the circuit diagram. Note the values of alternating current for various values of the frequency of ac. Plot the points on a graph sheet and draw the parallel resonance curve. Find the resonant frequency (f_R) the resonant alternating current (I_{MIN}) from the graph. Find the corresponding to the alternating current $\sqrt{2}\, I_{MIN}$, the frequencies f_A and f_B from the graph and calculate the bandwidth ($\Delta f = f_B - f_A$).

Calculate the experimental value of the quality factor: $Q = f_R/\Delta f$.

Evaluate the unknown inductance: $L = 1/4\pi^2 f^2_R C$

Calculate the theoretical value of the quality factor: $\mathrm{Q} = \frac{1}{\mathrm{R}}\sqrt{\frac{L}{C}}$.

Observations and Calculations:

Series Resonance :

Resistance, R = ...Ω

Capacitance, C = ... F

From the graph, resonant frequency, f_R = ... kHz

Maximum current. I_{MAX} = ... mA

$$\frac{\mathrm{I_{MAX}}}{\sqrt{2}} = \text{..................................} \text{ mA}$$

Series Resonance:

Frequency $\boldsymbol{f}$ **(kHz)**	**Current** $\boldsymbol{I}$ **(mA)**

f_A = ... kHz f_B = ... kHz

Band width: $\Delta f = f_B - f_A$ = ... kHz

Inductance:

$$L = \frac{1}{4\pi^2 f_R{}^2 C} = \rule{5cm}{0.4pt}$$

$$= \text{............................ H}$$

Theoretical value of the quality factor:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \rule{3cm}{0.4pt} = \text{...........................}$$

Experimental value of the quality factor:

$$Q = \frac{f_R}{\Delta f} = \rule{2.5cm}{0.4pt} = \text{...........................}$$

Parallel Resonance:

Frequency ***f*** **(kHz)**	**Current** ***I*** **(mA)**

Resistance: R = ...Ω

Capacitance. C = ... F

Resonant frequency f_R = ... kHz

Minimum current. I_{MIN} = ... mA

$\sqrt{2}\ I_{MIN}$ = ... mA

f_A = ...kHz, f_B = ... kHz

Band width: $\Delta f = f_B - f_A$ = ... kHz

Inductance:

$$L = \frac{1}{4\pi^2 f_R^{\,2} C} = \underline{\qquad\qquad\qquad\qquad\qquad\qquad}$$

$$= \text{............................ H}$$

Theoretical value of the quality factor:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \underline{\qquad\qquad\qquad\qquad} = \text{...........................}$$

Experimental value of the quality factor:

$$Q = \frac{f_R}{\Delta f} = \underline{\qquad\qquad\qquad\qquad} = \text{...........................}$$

Result:

Mean value of the inductance, L =...................................... H

Quality Factor	Series	Parallel
Theoretical		
Experimental		

*****

Review Questions:

1. What do you mean by resonance in electrical circuits?
2. Why the current is maximum at resonance frequency in the case of series resonance circuit? Explain.
3. What is the physical significance of quality factor ?
4. What are the applications of LCR circuit ?

Reference Book: Physics, Vol 2, 6 ed, by Serway & Jewett, 2004, Thomson Brooks / Cole

Ex. No.: 7 Date:..............................

WAVELENGTH OF LASER USING DIFFRACTION GRATING

Aim: To determine the wavelength of the given laser beam using a diffraction grating.

Apparatus: Diffraction grating, laser, measuring scale, screen etc.

Principle: An arrangement of large number of equidistant parallel slits constitutes a grating. It is prepared by drawing fine lines extremely close together on the surface of an optically flat glass plate using a diamond point. The lines act like opacities and region between two lines act like transparencies. When a light beam of wavelength λ is incidenton a transmission grating (with *N* number of slits per unit length) normally, the diffracted beams of m^{th} order are observed at angles θ with respect to the undeviated beam (zeroth order beam), on either side. The relation between these parameters is, $\sin\theta = m N \lambda$.

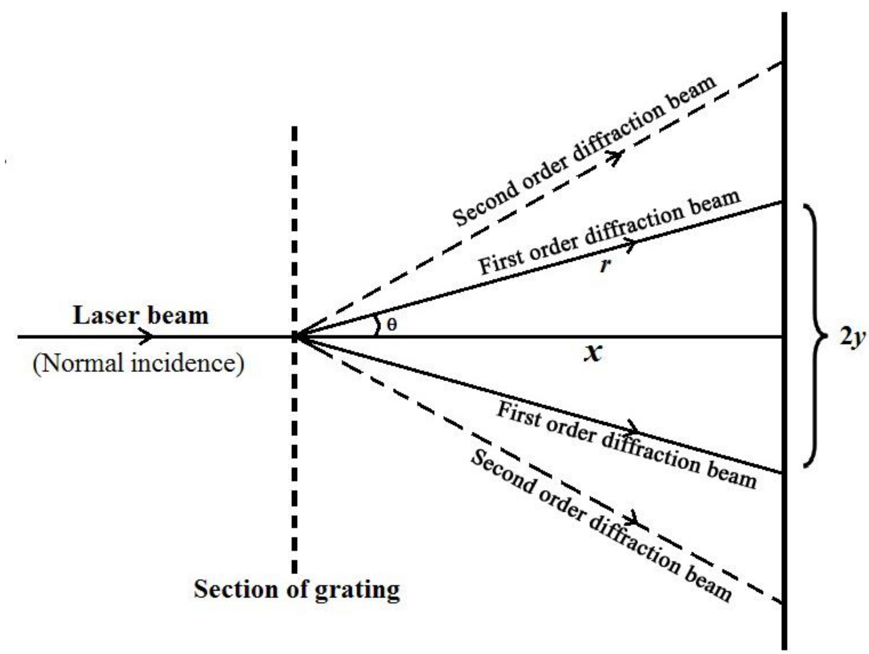

Fig : Schematic representation of diffraction of light through grating

Procedure: Switch on the laser unit and adjust the laser beam to be (approximately) normal to the surfaces of the grating as well as the screen. Identify the spots on the screen, most intense one due to undeviated beam (zeroth order) and two others two due to first order diffracted beams on either side of the zeroth order. Measure the distance 2*y* between the spots due to first order diffracted beams, and the normal distance (*x*) of the screen from the grating. Repeat the measurements for the second (and third) order diffracted beams. Calculate $r = \sqrt{x^2 + y^2}$ and mean value of $\sin\theta = \frac{y}{r}$, where θ is the diffraction angle. Calculate the wavelength of the laser beam using $\lambda = \frac{\sin\theta}{m\,N}$, where *m* is the order of the diffracted beam and *N* is the number of slits per unit length in the grating.

Observations and calculations:

N is the number of slits per unit length in the given grating.

Measurement of m^{th} order diffraction angle θ:

N **(m^{-1})**	**Order** ***m***	***x*** **(m)**	***2y*** **(m)**	***y*** **(m)**	$r = \sqrt{x^2 + y^2}$ **(m)**	$\sin\theta = \frac{y}{r}$	$\lambda = \frac{\sin\theta}{m\,N}$ **(m)**
6×10^5	1						
3×10^5	2						
1×10^5	3						

Mean λ = ...nm

Result:

The wavelength of the given laser beam is =...................................... nm.

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Review Questions:

1. What is LASER ?
2. Define the phenomenon of diffraction of light?
3. What is grating ? Mention grating equation.
4. What happens to the diffraction pattern when the distance between slits within the grating is increased?
5. What happens to the diffraction pattern when the number of slits within the grating (with same grating spacing) is reduced?

Reference Book: Course of Experiments with He-Ne Laser 2001, New Age International, New Delhi