



A LAB TEXT BOOK ON

PHYSICS

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PREFACE

Physics forms a core subject which is taught to students of all disciplines of engineering in all the technical universities . The study of this subject is aimed at developing a through understanding of the basic concepts and principles of the Physics and their applications through the Lab work . Laboratory experimentation gives the clear understanding of the subject and opportunity to develop the techniques . For this laboratory manual is designed to meet the requirements of G.G.S.I.P (IInd Semester) students

Some special features of this Lab manual are

- A brief description of the apparatus has been included along with relevant theoretical discussion of the experiment so that a student actually reads and understands it before starting the experiment . The system of recording the observations in a tabular form has been encouraged so that the various readings can be compared .
- The precautions have not only been given at the end of the experiment but also have been included in the instructions so that a student actually observes them even when he is performing the experiment .

This book is prescribed and helpful for Laboratory Experiments . Students are advised to study and perform the experiments according to the instructions during their Lab work .

It is hoped that with all these & other features this book will prove very useful for the students .

Paper Code : ETPH-152
 Paper : Applied Physics Lab – II

P	C
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List of Experiments

- 1) To determine the value of e/m of electron by J.J.Thomson method .
- 2) To determine the low resistance by Carey Foster bridge after calibrating the bridge wire .
- 3) To determine the velocity of ultrasonic waves in a given liquid (say Kerosene oil)
- 4) To find the capacitance of a capacitor using flashing and quenching of a neon lamp.
- 5) To determine the temperature coefficient of resistance of platinum by means of Callendar and Griffith's pattern bridge .
- 6) To determine the Hall Effect in Semiconductors and determine
 - (A) Hall Coefficient and Hall voltage
 - (B) No. of charge carriers / unit volume
 - (C) Hall mobility and Hall angle .
- 7) To find the co-efficient of thermal conductivity of a bad conductor by Lee's method .
- 8) To determine the capacitance of a capacitor by discharging it through Voltmeter .
- 9) Find the internal resistance of leclanche cell using a potentiometer.
- 10) To draw the V-I characteristics of a forward and reverse bias junction diode and to draw the load line.
- 11) To find the value of Plank's constant and photo-electric work function .

Note :

Atleast 8 experiments must be carried out .

Proper error – analysis must be carried out with all the experiments .

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Note :

Atleast 8 experiments must be carried out .

Proper error – analysis must be carried out with all the experiments .

EXPERIMENT 1

AIM :- To determine the value of e/m for an electron by Thomson's method using bar magnets.

APPARATUS USED :- A cathode ray tube fitted on a wooden stand provided with two arms perpendicular to the axis of the tube and having scales with zero at the point where the central line of the arms cuts the axis of the tube; a power supply unit capable of giving the accelerating D.c. voltage for the cathode ray tube and the deflecting D.C. voltage for the electric field through a reversing key with suitable voltmeters, two bar magnets, a compass box, a compass needle, etc.

THEORY :- The value of e/m can be determined by the method originally used by Prof. J.J. Thomson

The apparatus consists of a cathode ray tube which has three essential parts.

(i) The electron gun. This part consist of the cathode K and the anode A. It produces, accelerated and focuses the electrons into a fine beam so as to produce a small bright spot on the fluorescent screen S.

(ii) The screen. The screen S is coated with some fluorescent material like zinc sulphide etc. so that a greenish blue spot of light is observed where the electron beam impinges upon the screen. A transparent mm graph is attached to the screen to note the exact position of the fluorescent spot.

Measurement of e/m and Electronic Charge

(iii) The electric and magnetic deflecting system. Two plates P and Q are fitted in the tube symmetrically on either side of the electron beam so that an electric field perpendicular to the plane of the paper can be applied between them.

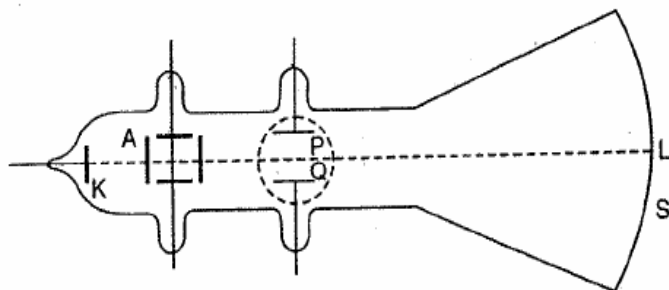


Figure 1.

A magnetic field can also be applied at the same place in a direction perpendicular to the direction of the electric field i.e. in the plane of the paper. Thus the deflection of the cathode rays due to the electric as well as the magnetic, field takes place in a direction perpendicular to the plane of the paper.

To apply the magnetic field the cathode ray tube is fitted on a wooden stand provided with two arms, one on either side perpendicular to the direction of the electron beam. A

scale is marked on each arm which gives the distance from the axis of the cathode ray tube. When two bar magnets are placed with their lengths parallel to the arms with their opposite poles towards the cathode ray tube, these produce a uniform magnetic field exactly at the same place where an electric field produced when a potential difference is applied between the plates P and Q.

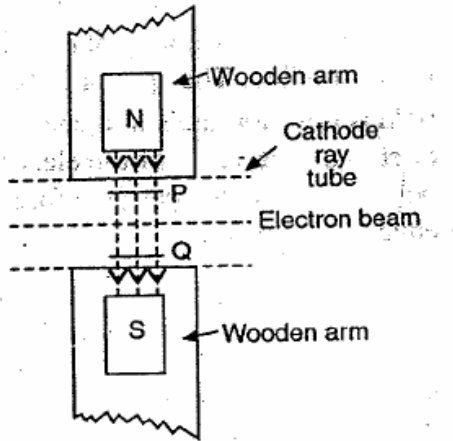


Figure 2

Theory. Let E be intensity of the electric field applied between the plates P and Q in a direction perpendicular to the plane of the paper then the force acting on the electron of charge e

$$= Ee$$

This force acts at right angles to the direction of motion of the electron. The electron, therefore, moves along a circular path within the electric field and on leaving the field flies off tangentially to the path meeting the screen at M_1 or M_2 depending up to the direction of the electric field as shown in Fig. 3. (a) and (b). When a magnetic field B is applied in the plane of the paper perpendicular to the direction of the beam as show in in figure 4. (a) then according to Fleming's left hand rule the beam is deflected upward cut of the paper in a direction perpendicular to both, the direction of motion of the electron and that of the field.

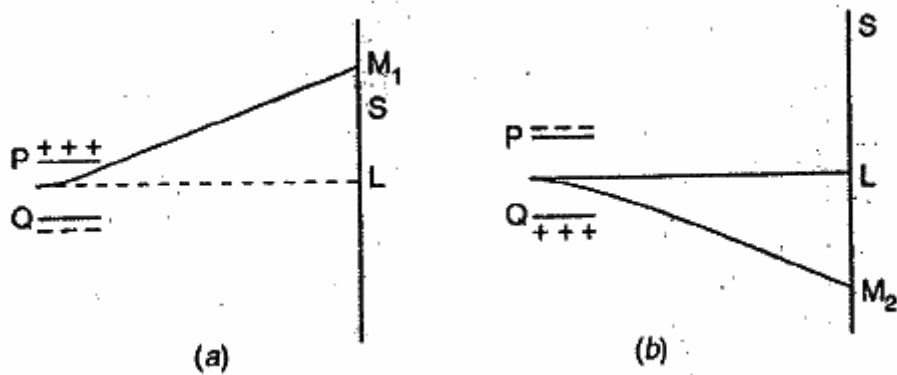


Figure 3

When the magnetic field is applied as shown in Figure 4. (b) the electron beam is deflected downward into the paper. If v is the velocity of the electrons in the beam, then magnitude of the force acting on each electron = $B e v$. As this force also acts at right angles to the direction of motion of the electron, the electron moves along a circular path in the magnetic field and on leaving the field flies off tangentially meeting the screen at M_1 or M_2 as explained above.

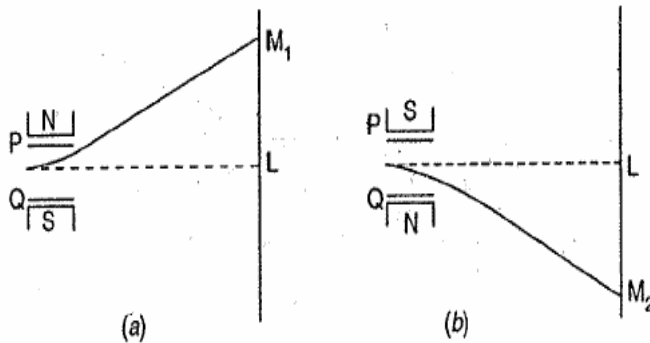


Figure - 4

If r is the radius of the circular path along which the electron moves in the magnetic field, then

$$B e v = \frac{mv^2}{r}$$

Or
$$\frac{e}{m} = \frac{v}{rB} \quad \dots\dots(i)$$

To find the velocity of electron v : To find the value of V , one of the fields say the magnetic field is first applied. The spot of light moves from its initial position to the position say M_1 . The electric field is now applied simultaneously so as to produce deflection of the electron beam in the opposite direction. The value of the electric field is so adjusted that the spot of light comes back to its initial position. In such a case the forces acting on the electron due top the electric and magnetic fields are equal and opposite.

$\therefore Ee = B e v$

Or
$$v = \frac{E}{B}$$

Substituting in (i), we have

$$\frac{e}{m} = \frac{E}{rB^2} \quad \dots\dots(ii)$$

To find the radius r of circular path. To find the value of r , the radius of the circular path in the magnetic field, note the position f the luminous spot on the screen when no field is applied and again when a field B is applied. Let the deflection of the spot be $y = LM_2$ as shown. The circular path of the beam OR in the magnetic field is as shown in Figure 2. The beam leaves the magnetic field at R tangentially to the path and meets the screen at M_2 so that $M_2 R$ produced meets OX in T . Draw OC and RC perpendiculars to OL and RM_2 respectively meeting at C , then C is the centre of the circular OR and $OC = CR$ radius of the circle = r

Now
$$\angle OCR = \angle LT M_2 = \theta$$

$$\therefore \tan \theta = \frac{LM_2}{LT} = \frac{OX}{OC}$$

$$\therefore r = OC = \frac{LT \times OX}{LM_2}$$

Now OX is very nearly equal to the length of the region in which the magnetic field is applied. This is also equal to the length of the region in which the electric field is applied. I.e. the length of the plates P and Q. Let it be = l (This is generally given by the makers).

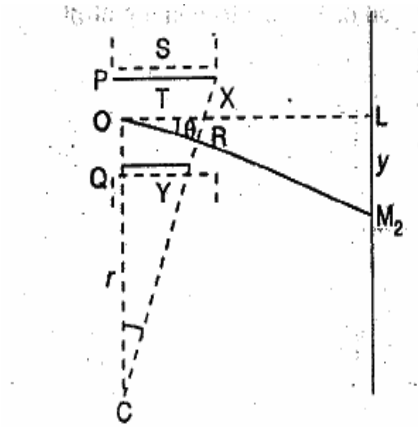


Figure 5

Measurement of e/m and Electronic Charge

LT is the distance of the centre of the screen from the centre of the region of the magnetic field (or electric field). Let it be = L

$$\therefore r = \frac{Ll}{y}$$

Substituting in (ii), we have

$$\frac{e}{m} = \frac{yE}{LlB^2} \quad \dots\dots (iii)$$

The electric field $E = \frac{V}{d}$ where V is the potential difference applied between the plates P and Q and d the distance between the plates (d is also given by the markers).
 Substituting in (iii), we have

$$\frac{e}{m} = \frac{yV}{LldB^2}$$

When V is in volts, B in Tesla and y, L, l, and d in meters e/m is in Coulomb/kg.

PROCEDURE :

(1) Draw the North South line using a compass needle. Also draw the East-West line. Place the cathode ray tube fitted in the wooden frame with its axis along the North South line so that the arms of the frame lie along the East West line.

(2) Connect the cathode ray tube to the power supply unit. Switch on the current and wait till a luminous bright spot appears on the screen. Adjust the brightness and focus controls so as to get a sharp bright point spot in the middle of the screen. Note the initial position of the spot on the scale fitted on the screen.

(3) Now apply a suitable deflecting voltage so that the luminous spot is deflected by about 0.5 to 1.0 cm. Note the deflecting voltage V and the position of the spot. Measure the distance through which the spot has moved and let it be y .

(4) Place the bar magnets symmetrically on either side of the cathode ray tube along the arms of the wooden stand on which the tube is fitted such that their opposite poles face each other and their common axis is exactly at right angles to the axis of the cathode ray tube. Adjust the polarity as well as the distance of the magnets so that the luminous spot comes back to its initial position. When the adjustment is perfect note the distance of the poles of the magnets on the side nearer to the cathode ray tube. Let the distances be r_1 and r_2 .

(5) Remove the bar magnet, switch off the electric field applied to the deflecting plates and again note the initial position of the luminous spot. Reverse the polarity of the potential difference applied to the electric deflecting plates with the help of the reversing switch fitted in the power supply unit thereby reversing the electric field. Again note the final position of the luminous spot and calculate y .

Again place the bar magnets on the arms of the wooden stand as in the previous step and adjust their polarity as well as the distance so comes back to its initial position. When the adjustment is perfect again note the distances of the poles of the magnets on the side nearer to the cathode ray tube. Let the distances be r'_1 and r'_2 . Switch off the power supply.

(6) To find the value of the magnetic field B , carefully remove the magnets and the cathode ray tube from the wooden stand. Place the compass box (of a deflection magnetometer or tangent galvanometer) such that its centre lies exactly on the point where the common axis of the bar magnets and the axis of the cathode ray tube intersect. Rotate the compass box about its vertical axis so that the pointer lies along the 0-0 line.

Place the magnets exactly in the same positions as in step 4 at distances r_1 and r_2 . This produces a deflection in the magnetometer compass box and the two ends of the pointer give the deflection. Let the readings be θ_1 and θ_2 .

Now place the magnets exactly, in the same positions as in step 5 at distances r'_1 and r'_2 and again note the deflections θ'_1 and θ'_2 from the two ends of the pointer of the compass box. The mean of these four deflection θ_1 , θ_2 , θ'_1 and θ'_2 gives the mean deflection θ . If B_H is the horizontal component of earth's magnetic field, then

$$B = B_H \tan \theta$$

(7) Take two more sets of observations by changing the value of V and hence that of the electric field.

Observations. (Data provided on the cathode ray tube by the manufactures).

Length of the deflecting plate P or Q = l = m

Distance of the screen from the centre of the plates L = m

Distance between the deflecting plate P and Q d = m

Sl. No.	Applied Voltage V	DIRECT FIELD								REVERSED FIELD					
		Position of Spot			Magnetic pole and Distance					Position of Spot			Magnetic Pole and Distance		
		Initial	final	Deflection y in met	Pole	r ₁	Pole	r ₁	Initial	Final	Deflection y in met.	Pole	r' ₁	Pole	r' ₂
1	V ₁ =										Y ₁ =				
2	V ₂ =										Y ₂ =				
3	V ₃ =										Y ₃ =				

Horizontal component of earth's field B_H = Wb/sq.m (Tesla)

For determination of B

Sl. No.	Applied Voltage V	Reading of two ends of pointer when mag. Poles are at r ₁ and r ₂		Reading of two ends of pointer when mag. Poles are at r' ₁ and r' ₂		Mean θ	B = B _H tanθ
1	V ₁						B ₁
2	V ₂						B ₂
3	V ₃						B ₃

CALCULATIONS :

(i)
$$e/m = \frac{y_1 V_1}{L d B_1^2} = C \text{ kg}^{-1}$$

(ii)
$$e/m = \frac{y_2 V_2}{L d B_2^2} = C \text{ kg}^{-1}$$

(iii)
$$e/m = \frac{y_3 V_3}{L d B_3^2} = C \text{ kg}^{-1}$$

Measurement of e/m and Electronic charge

$$(iii) e/m = \frac{y_3 V_3}{L d B_3^2} = C \text{ kg}^{-1}$$

$$\text{Mean } e/m = C \text{ kg}^{-1}$$

PRECAUTIONS :

- (1) The cathode ray tube must be set in the north south direction.
- (2) The luminous spot on the screen should be sharp, bright and in the middle.
- (3) The deflecting voltage must produce a deflection of the order of 0.5 to 1.0 cm.
- (4) The axis of the bar magnets and the axis of the cathode ray tube must be exactly at right angles and in a horizontal plane.
- (5) The deflecting voltage must be reversed to produce the deflection of the spot of light in the opposite direction and the magnetic field must also be reversed to bring it back to initial position.
- (6) The cathode ray tube must be handled carefully.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 2

AIM : To find the low resistance by Carey Foster bridge after calibrating the bridge wire.

APPARATUS USED : Carey-Foster bridge, two equal resistance, thick copper strips, a fractional resistance box (or standard fractional resistance coils), a cell, connecting wires, a sensitive galvanometer, a jockey and a key.

THEORY : The arrangement of Carey-Foster bridge is similar to Wheatstone bridge. As shown in Figure (...), P and Q are the two ratio arms, X along with the resistance of wire aD and Y along with the resistance of the wire bD form the other two arms.

If ρ is the resistance per cm of the wire, λ_1 and λ_2 the end resistances at a and b respectively, and a balance point is obtained at D, where $aD = l_1$, then

$$\frac{P}{Q} = \frac{X + l_1\rho + \lambda_1}{Y + (100 - l_1)\rho + \lambda_2} \quad \dots\dots(i)$$

If now, X and Y are interchanged and the balance point is obtained at D' as show in Figure 1 such that a D' is equal to l_2 , then

$$\frac{P}{Q} = \frac{Y + l_2\rho + \lambda_1}{X + (100 - l_2)\rho + \lambda_2} \quad \dots\dots(ii)$$

Comparing (i) and (ii) and adding one to both sides, we have

$$\frac{X + Y + 100\rho + \lambda_1 + \lambda_2}{Y + (100 - l_1)\rho + \lambda_2} = \frac{X + Y + 100\rho + \lambda_1 + \lambda_2}{X + (100 - l_2)\rho + \lambda_2}$$

Or $Y + (100 - l_1)\rho + \lambda_2 = X + (100 - l_2)\rho + \lambda_2$

Or $Y - X = (l_1 - l_2)\rho$

Or $X = Y - (l_1 - l_2)\rho$

Thus, the difference between the two resistances is equal to the resistance of the bridge wire between the two balance points. Further the above relation is free from the end correction of the total length of the bridge wire.

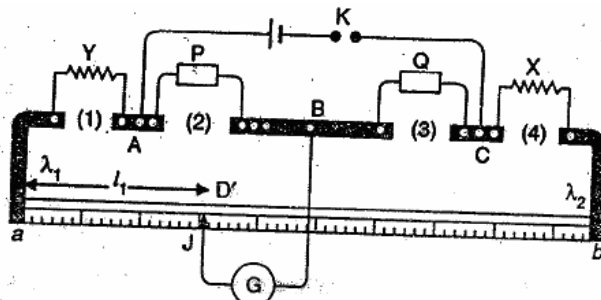


Figure 1

PROCEDURE :

(1) Connections.

- (i) Draw a diagram showing the scheme of connection as in Figure 2. Mark the gaps 1, 2, 3 and 4 on the bridge.
- (ii) Clean the ends of the connecting wires and the thick copper strip with a sand paper.
- (iii) Connect the two equal resistance P and Q in the inner gaps 2 and 3. If P and Q are two resistance boxes, take out 5 ohm plug from either and make all other plugs tight. Connect the thick copper strip X in the gap 1 and the fractional resistance box by means of thick copper rods in the gap 4. Connect one terminal of the galvanometer to the central terminal B and the other to a jockey J. Connect the cell through a key between the points A and C. Show the connection to the instructor before passing the current.

(2) To test the connections. Make the plugs of the fractional resistance box tight by giving to each plug a slight twist. Put in the key K and touch the jockey on the wire at the end a. Note the direction of deflection. Now touch the jockey at the end b. If the direction of deflection is reversed the connections are correct.

(3) **To find ρ , the resistance per cm of the wire.** (i) Without taking out any plug from the fractional resistance box, adjust the position of the jockey to obtain a balance point and note the reading. Take out the key K. Interchange X and Y, put in the key K and obtain the balance point again. Note the reading.

The difference in the two positions gives us the resistance of the lead wires connected in the fractional resistance box (Y) and the resistance of the plugs, brass blocks etc. This shift is known as the correction and must be subtracted from the shift obtained in the subsequent readings to the correct shift. Let this be denoted by δl .

(ii) Take out 0.1 ohm plug from the fractional resistance box YU and after putting the K obtain the balance point. Note the reading and interchange X and Y. Again obtain the balance point and note it.

(iii) Repeat the observation with the values of Y equal to 0.2, 0.3, 0.4 and 0.5 ohm etc.

To find the low resistance. Disconnect the copper strip and connect either the given low resistance in the form of a small piece of wire W soldered to two thick copper strips S_1 and S_2 as shown in Figure 2 or the two turns coil of the tangent galvanometer in its place by pieces of short thick copper wires. Keeping the resistance in the fractional resistance box zero, find the balance point. Interchange the tangent galvanometer and the fractional resistance box and find the balance point again. Similarly repeat the observation by taking out 0.1, 0.2, 0.3, 0.4 and 0.5 ohm resistance from the fractional resistance box.

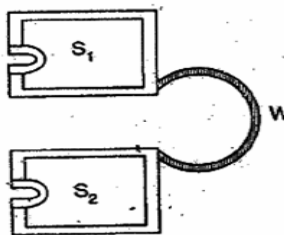


Figure 2

Observations: (a) Determination of ρ , the resistance per cm of the bridge wire.

Balance point with Y zero and X in left gap = x cm

Balance point Y zero and X in right gap = y cm

Correction to be applied (x - y) = δl cm

Sl. No.	X ohm	Y ohm	Position of balance point with copper strip in		Shift (l ₁ -l ₂) cm	Corrected Shift D = (l ₁ -l ₂) - δl	Resistance per cm $\rho = \frac{Y}{d}$
			Left gap (l ₁)	Right gap (l ₂)			
1	0	0					
2	0	0.1					
3	0	0.2					
4	0	0.3					
5	0	0.4					
6	0	0.5					

Mean ρ = ohm / cm

Note. To find the corrected shift subtract from (l₁ - l₂) the shift δl obtained when both X and Y are zero.

Sl. No.	Y ohm	Position of balance point with copper strip in		Shift (l ₁ -l ₂) cm	Corrected Shift D = (l ₁ -l ₂) - δl	Unknown resistance X = Y - ρd
		Left gap (l ₁)	Right gap (l ₂)			
1	0					
2	0.1					
3	0.2					
4	0.3					
5	0.4					
6	0.5					

Mean X = ohm

Note. If the unknown resistance X is greater than the known resistance y taken from the fractional resistance box, then l₁ is less than l₂. Hence the shift (l₁ - l₂) is a negative quantity.

If X is less than Y, I_1 is greater than I_2 and hence the shift ($I_1 - I_2$) is positive.

	Precautions.
1.	The ends of connecting wires, thick copper strip and the leads for the resistance box should be properly cleaned.
2.	The unknown low resistance should be connected to the bridge by thick copper leads.
3.	The plugs of the fractional resistance box should be tight.
4.	The batter key should be taken out while interchanging X and Y to avoid heating of the bridge wire.
5.	In order that the bridge may be sensitive, the resistances of the four arms should be nearly of the same order. This is why P and Q should not be very large.
6.	The jockey should be touched gently and should not be kept pressed on to the wire while shifting it from one point to the other.
7.	The difference between X and Y should not be more than the resistance of the bridge wire.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 3

AIM : To find the velocity of ultrasonic waves in a given liquid (say kerosene oil).

APPARATUS USED : A glass cell, kerosene oil, quartz crystal slab fitted with two leads, ultrasonic spectrometer, convex lens, sodium lamp, radio frequency oscillator with frequency measuring meter, spirit level etc.

THEORY : We can find the velocity of sound in a liquid (say kerosene oil) using ultrasonic.

A quartz crystal Q is placed between two metal plates. These two plates are connected to an audio frequency oscillator whose frequency is so adjusted that the crystal vibrates in resonance with the oscillator. Due to longitudinal compression and rarefactions of the waves, ultrasonic are produced. Those waves are reflected by the reflector R (figure 1). Due to superposition of the forward and reflected waves longitudinal stationary waves are produced in the medium and consequently fixed values of nodes and antinodes can be assigned. At nodes density is maximum and at antinodes density is minimum. The arrangement is just similar to diffraction grating and so is called acoustic grating.

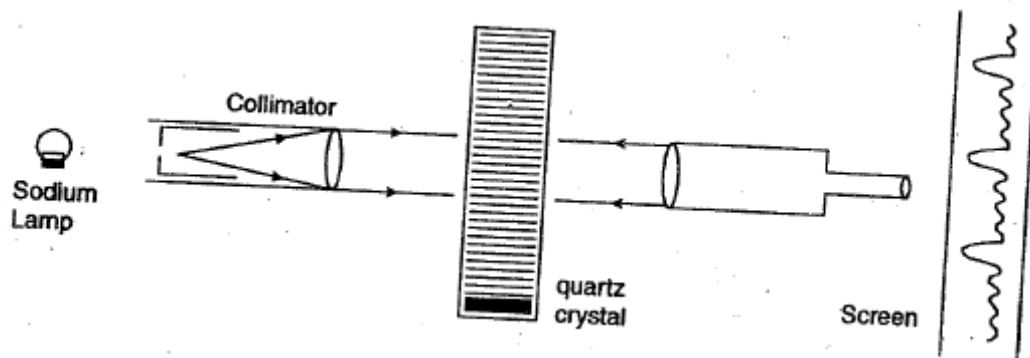


Figure 1

The above arrangement is suitable for measurement of wavelength and velocity of ultrasonic in a medium.

As shown in figure 1 the acoustic grating is mounted on the prism table of a spectrometer. A parallel beam of sodium light from collimator is incident normally on the acoustic grating and the diffracted light is viewed through the telescope. As shown, the diffraction pattern consists of a central maximum and principal maxima on either side. The position of the principal maxima are given by the relation.

$$d \sin \theta_n = n\lambda \quad \dots\dots(1)$$

where $\lambda \rightarrow$ wavelength of sodium light

$d \rightarrow$ distance between two nodal or antinodal waves

$\theta_n \rightarrow$ angle of diffraction for nth order

And $n \rightarrow 1, 2, 3$ etc. i.e. order of spectrum

If n, θ_n and λ are known then d can be found from equation (1)

If λ_m is the wavelength of ultrasonic through the medium, then

$$d = \frac{\lambda_m}{2}$$

or $\lambda_m = 2d$

If the resonant frequency of the piezoelectric oscillator is N, the velocity of ultrasonic waves is given by

$$v = N\lambda_m \\ = 2Nd$$

The above method is useful for determination of velocity of ultrasonic waves through liquids and gases at various temperatures.

$$\lambda_m = \frac{n\lambda D}{d_n}$$

Ultrasonic Spectrometer

The ultrasonic spectrometer is just like an optical spectrometer with the following three parts.

a) A Collimator. It is brass tube with a fine adjustable slit at one end and an achromatic convex lens at the other end fitted with a rock and pinion arrangement.

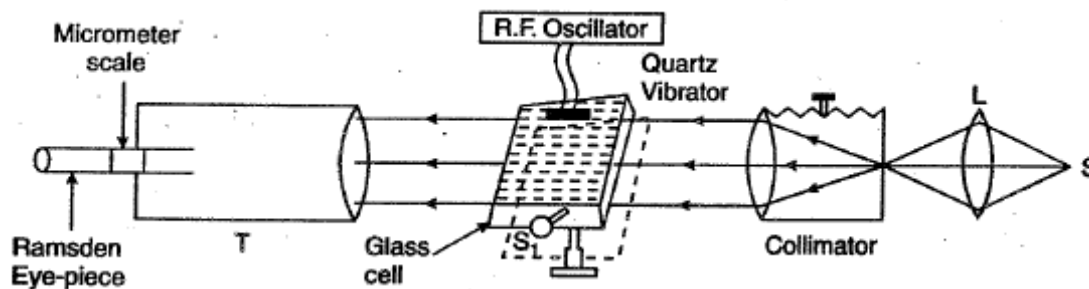


Figure 2

b) A telescope. It consists of an objective of large focal length and a Ramsden eye piece provided with a horizontal micrometer scale.

c) A table. The cell containing the experimental liquid is placed on the table. Which is fitted with a screw S_1 to give it a horizontal motion and a screw S_2 to give it a vertical motion.

PROCEDURE :

- 1) Make the setting of the telescope and collimator of the ultrasonic spectrometer in the same way as is done in case of optical spectrometer.
- 2) Place the glass cell containing the experimental liquid on the spectrometer table with its opposite parallel sides facing the telescope and the collimator respectively.
- 3) Mount the quartz crystal slab in its holder and in it in the liquid near a wall of the glass cell so that the ultrasonic waves produced by the crystal travel in the liquid in a direction perpendicular to that of the incident light. Connect the leads of the crystal slab with the output terminals of the R. F. oscillator.

- 4) Put the quartz crystal in its holder and place it in the liquid near a wall of the glass cell so that the ultrasonic produced by the crystal move perpendicularly to the direction of incident light. Make the connection of R.F. oscillator with the leads of crystal slab.
- 5) Focus the light from sodium lamp on the slit of collimator. Look through the telescope eye-piece and get a well defined image of the slit at the centre of the micrometer scale fitted in the eye-piece of the telescope.
- 6) Switch on the R.F. oscillator so that the ultrasonic waves are produced in the liquid. Make the adjustment of frequency from the oscillator so that it becomes equal to the natural frequency of the crystal slab and resonance takes place and diffraction images of the slit will be visible through the telescope. An enlarged view of diffraction pattern is show in figure 3. Note down the frequency of the R.F. oscillator and keep it constant throughout the experiment.

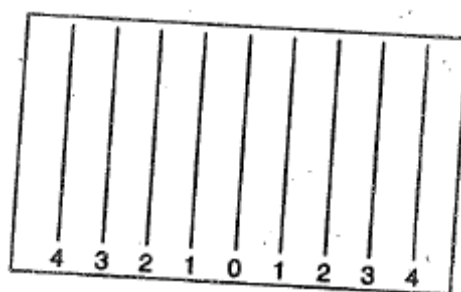


Figure 3

- 7) Note down the distance of various order diffraction image on both sides of the central zero using the micrometer scale of the eye piece of telescope.
- 8) Also measure the distance D between the objective lens of telescope and the crosswire (micrometer scale). It will correspond to the focal length of the objective lens and is normally provided by the manufacture of the instrument.

OBSERVATIONS :

Wavelength of Sodium light $\lambda = 5893 \times 10^{-10} \text{ m}$
 Room temperature = $^{\circ} \text{C}$
 Distance D = cm
 Frequency of the oscillator used $\nu = \text{Hz}$
 Least count of the micrometer scale = mm

S. No.	Order of diffraction maxima N	Position of diffracted image in cm						$d_n = \frac{x - y}{2}$	$\frac{d_n}{n} \text{ cm}$
		Left of central image			Right of central image				
		Main scale	Vernier scale	Total x	Main scale	Vernier scale	Total y		

1									
2									
:									
:									
10									

Mean value of $\frac{d_n}{n} = \text{cm} = \text{m}$

Wavelength of ultrasonic waves

$$\lambda_n = \frac{n}{d_n} \lambda D = \frac{\lambda D}{d_n} = m$$

Velocity of ultrasonic waves = $v\lambda = \dots\dots \text{ms}^{-1}$

PRECAUTIONS	
1.	The diffraction pattern should be sharp and narrow.
2.	The glass cell should be thoroughly cleaned and filled with the liquid.
3.	The crystal slab should be set in such a way that the ultrasonic waves produced by it travel be kept constant during the experiment.
5.	The crystal slab should be immersed completely in the liquid and should touch neither the bottom nor the side of the walls.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 4

AIM : To find the capacitance of a capacitor using flashing and quenching of a neon lamp.

APPARATUS USED : A capacitor of unknown capacitance, capacitors of known capacitance (say 0.1, 0.2, 0.5 μF), a neon flashing lamp, a resistance of about 1 meg ohm, regulated D.C. power supply capable of giving upto 150 volts and 5 keys.

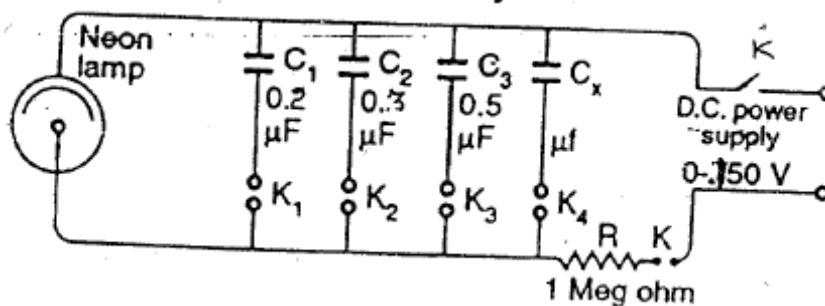


Figure (1)

Note : Neon lamps intended to be connected direct to H.T. have a ballast resistor of about 2000 ohm sealed into the cap to limit the current. This must be removed for this experiment. Alternatively small neon flash bulbs without any resistor sealed in are available from radio dealers.

THEORY :

Flashing and quenching of a neon bulb. A neon bulb is placed in parallel with a capacitor and connected to D.C. supply which can be continuously increased from 0 to 150 volt through a high resistance of about 1 meg. Ohm. The voltage is slowly increased to a value say V_1 when the lamp flashes and begins to glow. As soon as the neon lamp flashes, it becomes conducting and the capacitor begins to discharge through it. It continues to do so until the extinction (or quenching) potential V_2 is reached when the neon lamp ceases to glow and stops conducting. The capacitor then again begins to charge till the flashing potential V_1 is reached when again the lamp flashes and begins to glow. The process is repeated, During the time the capacitor is charging the neon lamp does not glow. In other words, the total time t between two consecutive flashes is equal to the time taken by the voltage first to fall from the flashing potential V_1 to quenching potential V_2 (discharge) and then to rise from V_2 to V_1 (charging). This flashing and quenching time can be determined by noting the time taken by the lamp to produce say 20 consecutive flashes and quenches.

If t_1 is the time taken by the capacitor voltage to fall from V_1 to V_2 and t_2 is the time taken by the voltage to rise from V_2 to V_1 , then

$$V_2 = V_1 e^{-t_1/CR}$$

Or

$$t_1 = -CR \log_e \frac{V_2}{V_1}$$

And

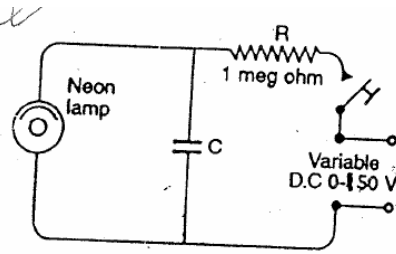
$$V_2 = V_1(1 - e^{-t_2/CR})$$

Or

$$t_2 = -CR \log_e \left(1 - \frac{V_2}{V_1} \right)$$

∴

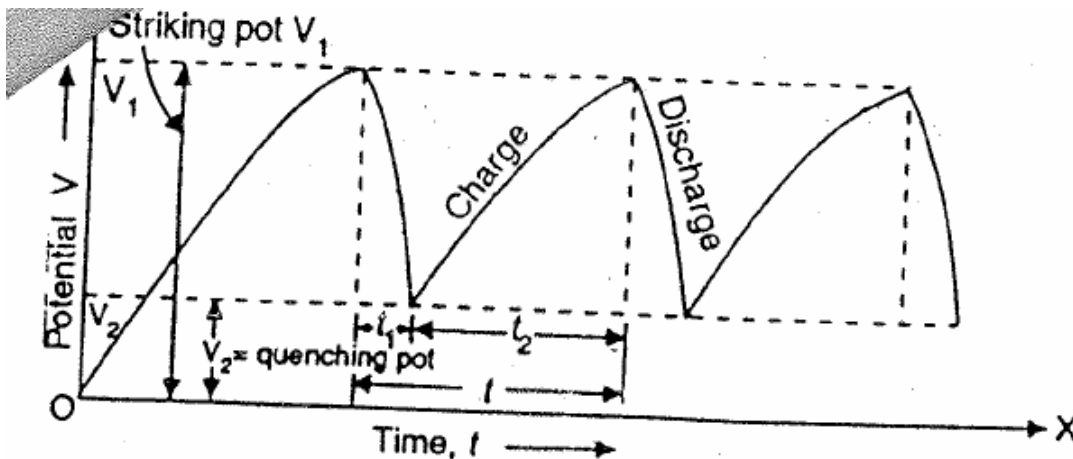
$$t = t_1 + t_2 = C \left[-R \log_e \frac{V_2}{V_1} - R \log_e \left(1 - \frac{V_2}{V_1} \right) \right]$$



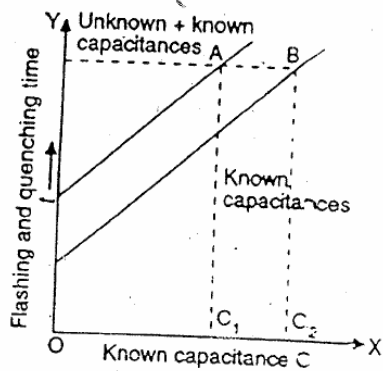
As R, V_2 and V_1 have constant fixed values, the function within brackets is a constant., Let it be = k

∴

$$t = kC$$



Determination of capacitance. To find the value of an unknown capacitance a second graph is plotted by noting the flashing and quenching time for the sum of the unknown capacitance and each of the unknown capacitances. The two graphs are parallel straight lines as shown. To calculate the value of the unknown capacitance draw a straight line AB parallel to X-axis corresponding to any value of flashing and quenching time cutting the two graphs at A and B respectively. If C_1 and C_2 are the values of the known capacitances corresponding to the points A and B respectively C_x the unknown capacitance and C_s the stray capacitance of the circuit then.



Total capacitance corresponding to point A

$$= C_s + C_1 + C_x$$

And total capacitance corresponding to point B

$$= C_x + C_2$$

Since the flashing and quenching time for both is the same

$$K(C_s + C_1 + C_x) = k(C_x + C_2)$$

Or $C_x = C_2 - C_1$

PROCEDURE :

1. Draw a diagram showing the scheme of connections as in Figure (1) and make connections accordingly.
2. Connect the capacitance C_1 in the circuit by putting in the key K_1 . Put in the key K and increase the power supply voltage slowly till the neon lamp just begins to flash. As it is connected in parallel.
 Remove the key K to disconnect the power supply. Put in the key K_4 so that the capacitors C_1 and C_x (of unknown capacitance) are connected in parallel and total capacitance is equal to their sum $C_1 + C_x$. Again put in the key K (see that the power supply voltage remains constant). Note the time of 20 flashes. Remove the keys K, K_4 and K_1 .
3. Repeat the experiment with capacitors C_2 alone and $(C_2 + C_x)$; C_3 alone and $(C_3 + C_x)$. Now put in the keys K_1 and K_2 so that the total capacitance $(C_1 + C_2)$ is in the circuit. Repeat the experiment with $(C_1 + C_2)$ and then with $[(C_1 + C_2) + C_x]$. Similarly repeat the experiment with $(C_1 + C_3)$ and $[(C_1 + C_3) + C_x]$, $(C_1 + C_2 + C_3)$ and $[(C_1 + C_2 + C_3) + C_x]$

OBSERVATION :

1 SI.No.	2 Known Capacitance	3 Time for 20 Flashes without C_x	4 Flashing and Quenching time t	5 Time for 20 Flashes with C_x	6 Flashing and Quenching time t
	$C_1 =$ $C_2 =$ $C_3 =$ $C_1 + C_2 =$ $C_1 + C_3 =$ $C_1 + C_2 + C_3$				

4. Plot two graphs (i) between values of capacitance in column 2 taken along X-axis and flashing and quenching time t in column 4 (without unknown capacitance) and (ii) between values of capacitance in column 2 and quenching and flashing time t in column 6 (with unknown capacitance) taken along the Y-axis. For three different values of flashing and quenching time draw three straight lines. Parallel to X-axis cutting the two graphs at A and B, C and D, and E and F respectively.

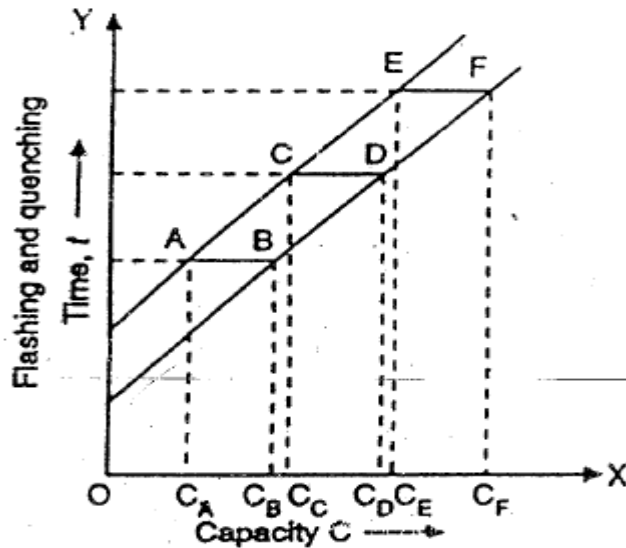


Figure (2)

The unknown capacitance

$$C_x = AB = C_B - C_A$$

$$= CD = C_D - C_C$$

$$= EF = C_F - C_E$$

Mean $C_x = \mu F$

PRECAUTIONS

1. The voltage from the D.C. power supply should remain constant throughout the experiment.
2. The resistor sealed in the cap of the neon lamp should be removed before using it for the experiment, otherwise a bulb without resistor should be used.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 5

AIM: To determine the temperature coefficient of resistance of platinum by means of Callendar and Griffith's pattern bridge.

APPARATUS : Platinum resistance thermometer, Callendar and Griffith's pattern bridge, a Leclanche cell, a galvanometer, beaker (600 c.c. capacity), electric stove, a decimal-ohm dial box, a mercury thermometer and connection wires.

THEORY : Callendar and Griffith's pattern bridge. For work at the undergraduate level such a piece of apparatus is manufactured. By Instrument & Chemicals Ltd. Ambala. The circuit diagram of the bridge is given in figure 1.

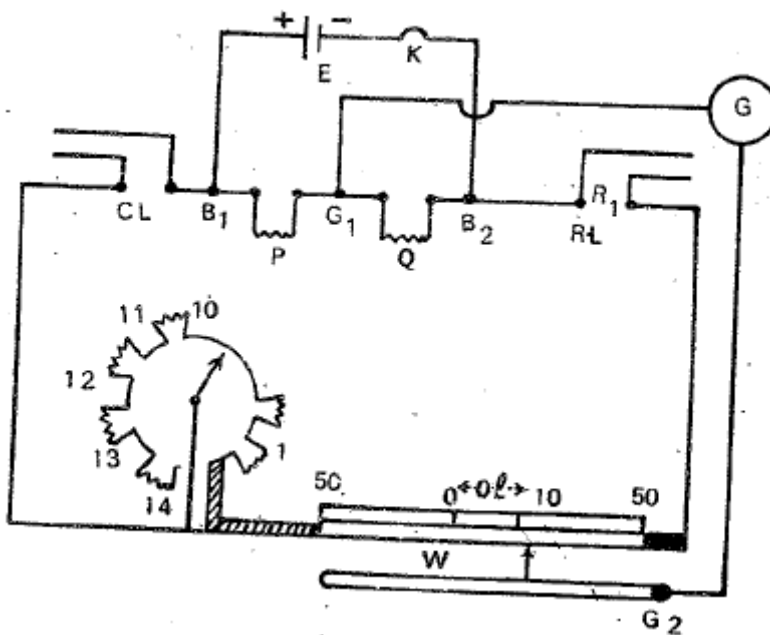


Figure 1

The ratio coils P and Q have equal resistance, so that the ratio is 1:1. CL and RL are the gaps for connecting the compensating and the resistance leads of the thermometer. R is a dial pattern resistance, each coil having a resistance of one ohm. In series with this is a stretched wire W, also of resistance one ohm. The scale for the reading of the length of the wire is graduated with zero in the middle and 50 division marks at either end. Thus the value ρ , the resistance per unit length of the bridge wire is 1/100 ohms per unit length.

Suppose with connections as shown in the figure above, the null point is at a length l measured from middle points of the wire. Let R_1 be the required resistance of the platinum wire, say at room temperature t_1 and R the resistance introduced in the dial box. Then

$$\frac{P}{Q} = 1 = \frac{y + R + (50 + l)\rho}{y + R_1 + (50 - l)\rho}$$

Where ρ is the resistance per unit length of the bridge wire and y is the resistance of the leads. From the above equation we have

$$y + R_1 + (50 - l)\rho = y + R + (50 + l)\rho$$

$$R_1 = R + 2l\rho \quad (a)$$

Where ρ is known, R_1 can be calculated from the observed values of R .

Similarly, if R_2 be the resistance of the platinum wire of the thermometer at a temperature t_2 , then

$$R_2 = R + 2l_2\rho \quad (b)$$

Knowing R_1 and R_2 , α can be calculated from the relation.

$$\alpha = \frac{R_2 - R_1}{R_2 t_2 - R_1 t_1}$$

PROCEDURE :

(I) Determination of electrical Zero of the bridge.

Connect the Leclanche cell through a key K across the terminals B_1 and B_2 and the galvanometer across G_1, G_2 . Put the dial box R at zero. Close the gaps CL and RL by thick copper strips.

Insert the plug of the key K of the cell circuit and determine the position of the null point by pressing the jockey in the neighbourhood of the middle of the wire. Note this position. This gives the position of the electrical zero of the bridge wire. For an accurate bridge it should be at zero of the scale – this zero of the scale being at the middle point of the wire and 50 division marks on either side being at the ends of the wire. The difference between the zero of the scale and the electrical zero may be termed as the zero error of the bridge. Due correction must be applied in subsequent observations.

(II) Determination of ρ , the resistance per unit length of the bridge wire.

Remove the copper strip from the gap CL . Connect a decimal ohm resistance box across CL . The dial box R stands at zero. Insert r and resistance r of, say, 0.3 ohm in the gap CL , by rotating the dial of the decimal ohm box and locate the null point on the bridge wire. Measure the length from the zero of the scale. Correct this length for the zero error of the bridge by subtracting from this length the zero error of the bridge with its appropriate sign. Let this corrected length be L_1 units. Then evidently, since $R = 0$,

$$R = 0.3 = 2L_1\rho$$

$$\text{Or } \rho = \frac{r}{2L_1} = \frac{0.3}{2L_1} \text{ ohm per unit length}$$

Repeat the observations by introducing resistance of value 0.4, 0.5, 0.6 ohm from the decimal – ohm dial box across CL . Calculate ρ from each set and find its mean value.

(III) Determination of R_1 and R_2 .

Disconnect the decimal ohm dial box from the gap CL and the copper strip from the gap RL .

Connect the compensation leads of the platinum resistance thermometer across CL and its resistance leads across RL .

Introduce a resistance of 2 ohms in the dial box R and locate the balance point on the bridge wire. (Usually the resistance of the thermometer lies between 2 and 3 ohms). Correct this length

for the zero error of the bridge wire and knowing the values of R , L and ρ , calculate R_1 from equation a.

By changing the value of R to 3 ohms, redetermine the value of R_1 . It may be noticed here that with R equal to 2 ohms, the balance point was on the positive side of the scale (i.e., on to the right of zero of the scale) whereas with R equal to three ohms, the balance point is obtained on the left hand side of the zero, i.e. on the negative side of the scale. In the latter case R_1 will be calculated from the relation

$$R_1 = R - 2\rho$$

Find the mean value of R_1 . Record the room temperature t_1 °C. Thus the resistance R_1 of the platinum coil is known at a temperature t_1 °C.

Next place the platinum resistance thermometer in a large beaker or container with water. Allow the water to boil by heating the container over an electric stove. Also put a mercury thermometer to record the temperature t_2 of boiling water.

When water in the container has been boiling for about ten minutes or so, introduce a resistance of 3 ohms in the dial, box R and locate the new balance point on the bridge wire, which will now be again on the positive side of scale. Repeat this observation after every two minutes, and when the reading does not change it can be assumed that the platinum coil has attained the temperature t_2 °C of boiling water, as recorded by the mercury thermometer. Note this length for the balance point and correct it for zero error. From a knowledge of the resistance R (-3 ohms), the corrected length l^1 for balance and Calculate R_2 from the equation (b)

Put R at 4 ohms and redetermine the value of R_2 . Compute the mean value of R_2 from those two determinations.

SOURCE OF ERROR AND PRECAUTIONS

- 1) The decimal ohm box should be preferably of dial pattern and should be connected by short, thick wires.
- 2) The cell circuit should be made on by the plug key only when observations are being taken; for the rest of the time, the plug should be out of the key. This would prevent unnecessary heating of the resistance coils due to the passage of current.
- 3) The galvanometer should be shunted by a low resistance wire to avoid excessive deflections in it when the bridge is out of balance the shunt should be removed when the exact position of the null point is being determined.
- 4) The jockey should be pressed gently over the bridge wire; and the contact between the jockey and the bridge wire should not be made while the jockey is being moved along.
- 5) To ascertain that the platinum coil has attained the temperature of boiling water, the position of the balance point must be found out every minute or every two minutes; if there is no shift in the balance point it can be assumed that the platinum coil has attained the temperature of boiling water. If there is any shift, it should be of a negligible order, a mm. or so. The mean of such close lengths should be taken to obtain the length for balance of the bridge.

CALCULATION FOR R₁ and R₂

Calculation for R₁ and R₂

From Set 1, R₁ = R + 2(l ± Z)ρ

$$=$$

$$= \quad \text{ohm}$$

From set 2, R₁ = R - 2(l ± Z)ρ

$$=$$

$$= \quad \text{ohm}$$

Mean value of R₁ = ohm

Similarly,

Mean value of R₂ = ohm

Hence

$$\alpha = \frac{R_2 - R_1}{R_2 t_2 - R_1 t_1}$$

$$=$$

$$= \quad \text{per } C^\circ$$

RESULT

The temperature coefficient of resistance for platinum = per C°.

Standard value of α = per C°

Percentage error =

SPACE FOR STUDENT WORK AREA

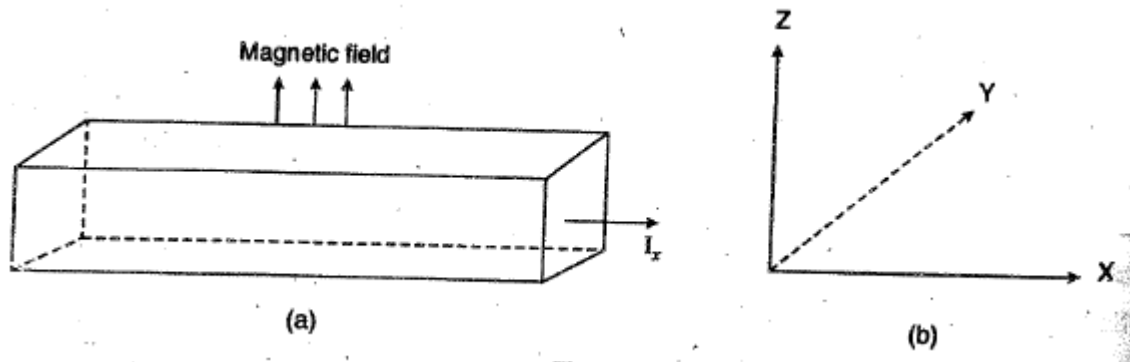
EXPERIMENT 6

AIM : To study the Hall effect in semiconductors and determine

- (A) Hall coefficient and hall voltage
- (B) No. of charge carriers / unit volume
- (C) Hall mobility and Hall angle.

APPARATUS USED : A semiconductor crystal slab of rectangular shape (thickness is 0.3 mm) search coil, electromagnet, millivoltmeter battery, ammeter, keys, flux meter for measuring magnetic fields, connecting wires. Etc.

THEORY : Hall effect is a magneto electric effect i.e. if a current I_x is made to pass through X-direction of a specimen slab and a magnetic field B_z is applied along Z direction, then the potential



Difference known as Hall potential is developed along Y-direction. The sign of the Hall potential thus developed is dependent on the nature of charge carriers.

So by noting the directions of Hall potential and the applied magnetic field, it is possible to know the nature of charge carriers by using Fleming's left hand rule.

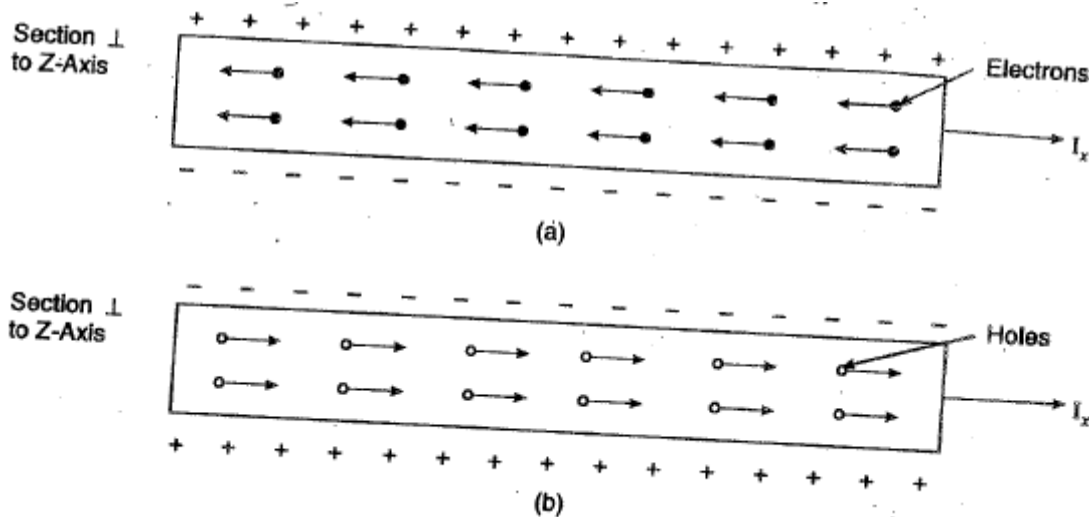


Figure 1

We can understand the development of hall potential as under:

Let E_x be the applied field along X-axis and B_z the magnetic field applied along Z-axis. This electric field exerts a force on the charge carriers (say electrons) and so accelerates the electrons which in turn may acquire a drift velocity v_x along X-direction.

Now the force on electron from Fleming's left hand rule is given by

$$F_m = q \vec{v} \times \vec{B} = -e \left(v_x \hat{i} \times B_z \hat{k} \right)$$

$$= -e v_x B_z \hat{j} \quad \dots\dots(1)$$

Which means that the force is along negative Y-axis and so the electrons get transferred from surface along positive Y-direction towards that along negative Y-direction, thereby establishing field along negative Y-direction and creating a Hall potential difference the surface towards positive Y-axis being at higher potential [Figure 1 (a)]. However if the charge carriers are holes the surface towards positive Y-axis would acquire a lower potential difference [Figure 1 (b)].

The drift velocity of carriers will acquire a steady value because the electric field produced is ultimately cancelled by the magnetic field.

We see from above discussion that Hall field developed is a function of:

- (a) Applied magnetic field B_z .
- (b) Current density i.e., current / unit area Mathematically, we have

$$E_H \propto J_x$$

$$E_H \propto B_z$$

Which may be written as

$$E_H = R_H J_x B_z \quad \dots\dots(2)$$

Where R_H is the constant of proportionality and is known as hall coefficient

If $J_x = 1 \text{ amp/m}^2$

And $B_z = 1 \text{ wb/m}^2$

Then $E_H = R_H \quad \dots\dots(3)$

So we may define hall coefficient as the numerical value of the Hall electric field produced by a unit current density and unit magnetic field.

Now we have the Lorentz force on a single electron given by

$$\vec{F} = q \left(\vec{E} + \vec{v} \times \vec{B} \right)$$

$$= -e \left(E \hat{j} + v_x \hat{i} + B_z \hat{k} \right)$$

$$= -e \left(E_y - v_x B_z \right) \hat{j} \quad \dots\dots (4)$$

And for steady state $F = 0, \therefore E_y = v_x B_z \quad \dots\dots (5)$

Where $E_y = E_H$ is the Hall electric field and V_x is steady drift velocity

If the thickness of the crystal along Y-direction be d , then we have

$E_H = V_H/d$ where V_H is the Hall potential developed.

So $V_H = E_H \cdot d = v_x B_z d$ (6)

Let n be the no. of charge carriers (say electrons / unit volume, then the current density may be given by

$$J_x = -nev_x \quad \dots (7)$$

Let b be the breadth of the specimen along Z-direction, then total current is given by

$$I_x = J_x A = -ne v_x bd$$

[∴ Area $A = \text{Length} \times \text{breadth}$]

Or drift velocity
$$v_x = \frac{-I_x}{nebd}$$

Hall coefficient
$$R_H = \frac{E_H}{J_x B_z}$$

$$= \frac{V_H / d}{B_z \left(\frac{I_x}{bd} \right)} = \frac{V_H}{I_x} \cdot \frac{b}{B_z} \quad \dots\dots\dots (8)$$

And value of ratio V_H/I_x can be determined graphically.

MOBILITY

Mobility (m_μ) is defined as the drift velocity acquired / unit applied electric field i.e.,

$$\mu = \frac{V_x}{E_x} \quad \dots\dots\dots(9)$$

Putting the value of v_x from eq. (9) in eq. (6), we get

$$V_H = m_\mu \cdot E_x B_z \cdot d \quad \dots\dots\dots(10)$$

∴
$$E_H = \frac{V_H}{d} = m_\mu \cdot E_x \cdot B_z$$

∴ Comparing equation (10) with equation (2), we have

$$R_H \cdot J_x \cdot B_z = m_\mu \cdot E_x \cdot B_z$$

∴ mobility
$$m_\mu = R_H \cdot \frac{J_x}{E_x} = R_H \cdot \sigma \quad \dots\dots\dots (11)$$

Where $\sigma = J_x/E_x$ is known as the electric conductivity of the specimen Putting the value of R_H from equation (8) in equation (11), we have.

Hall mobility

$$\begin{aligned}
 m_{\mu} &= \left(\frac{V_H \cdot b}{I_x \cdot B_z} \right) \frac{J_x}{E_x} \\
 &= \frac{E_H \cdot d}{I_x \cdot b \cdot d} \frac{b}{B_z} \frac{J_x}{E_x} \\
 &= \frac{E_H}{E_x} \frac{1}{B_z} = \frac{\phi}{B_z} \quad \dots(12)
 \end{aligned}$$

Where ϕ is the Hall angle.

So knowing the value of magnetic field B_H and the Hall angle, Hall mobility m_{μ} can be found.

Hall angle. As we have discussed, a charge carrier may be an electron or a hole is under the action of simultaneous applied electric field E_x and the hall field ($E_y = E_H$) which are perpendicular to each other. So drift velocity of charge carriers make an angle with X-direction and this angle is called Hall angle and is given by

$$\text{Hall angle } \phi = \frac{E_H}{E_x} \quad \dots\dots\dots (13)$$

Let V_x be the applied potential difference along X-axis and let l_x be the length of the crystal along X-axis therefore by definition $E_x = V_x / l_x$ and so hall angle may be given by

$$\phi = \frac{E_{\theta}}{E_x} = \frac{V_H / d}{V_x / l_x} = \frac{V_H l_x}{V_x d} \quad \dots\dots\dots (14)$$

PROCEDURE :

1) Place the specimen in the magnetic field and complete the circuit as shown in figure 2. In the diagram we have V_x the voltmeter which measures the p.d. across the specimen and A is the ammeter which measures the current (I_x) through the specimen. mV is the millivoltmeter the measures the Hall p.d. developed along Y-axis.

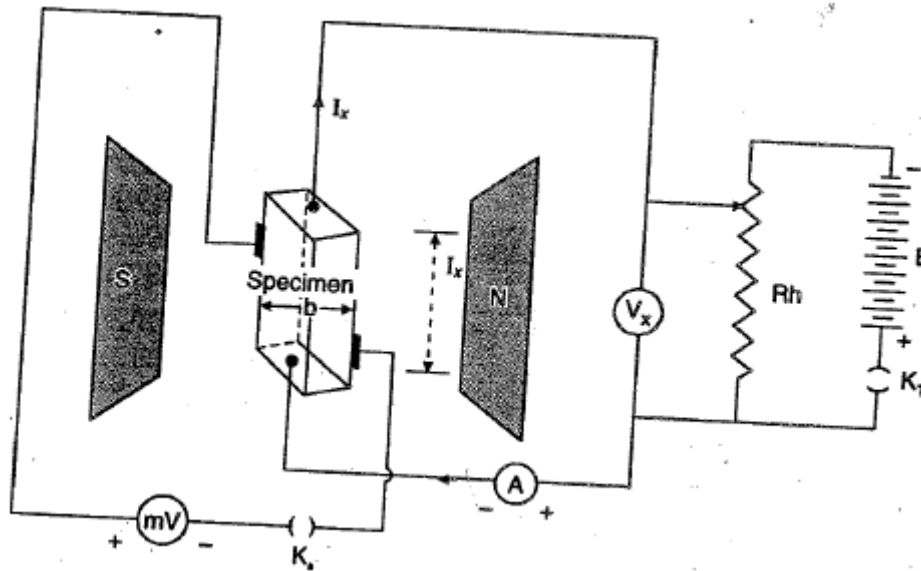


Figure 2

2) Apply the magnetic field by the switching on the electromagnet close key K_1 for current I_x to flow through the specimen. Note down the current I_x in ammeter and p.d. V_x across the specimen length.

3) Close Key K_2 also to bring the millivoltmeter also in the circuit and note down the hall potential difference $V_H (=V_y)$.

4) Plot a graph between hall voltage (V_H) Vs current (I_x). The slope of the graph gives V_H/I_x (figure)

5) Measure the magnetic field strength with a gaussmeter or fluxmeter. If the strength is measured by a gauss meter, then convert it into wb/m^2 using the relation.

$$1 \text{ gauss} = 10^{-4} \text{ wb/m}^2$$

6) Find the actual value of the field inside the crystal from the relation

$$B_z = \mu \cdot X$$

Where μ is the permeability of the specimen.

7) Find the length, breadth and thickness of the specimen.

Length of the crystal $l_x = \dots\dots\text{m}$

Breadth of the crystal $b = \dots\dots\text{m}$

Thickness of the crystal $d = \dots\dots$

Permeability of the specimen $\mu = \dots\dots$

Magnetic field measured by flux meter = $B_z = \dots \text{ wb/m}^2$

Actual magnetic field = $\mu B_z = \dots \text{ wb/m}^2$

S.No.	Current I_x (Amp)	Applied p.d. V_x (Volts)	Hall voltage Developed $V_H = V_y$ (volts)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

CALCULATIONS

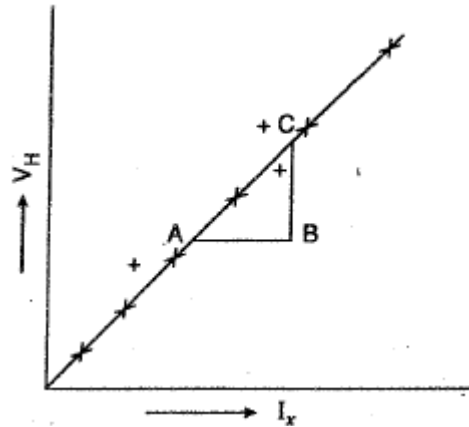
Hall coefficient

$$R_H = \frac{V_H}{I_x} \frac{b}{B_z} \text{ ohm-m}^3/\text{wb}$$

No of charge carriers / unit volume

$$n = -\frac{1}{eR_H} \text{ per m}^3$$

(take $e = 1.6 \times 10^{-19} \text{ C}$)



$$\text{Hall angle } \phi = \frac{V_H}{V_x} \cdot \frac{I_x}{d} \text{ Radians}$$

Mobility $m_\mu = \phi/B_z$ radians m^2/wb

RESULTS

From the graph between V_H and I_x find hall coefficient, which corresponds to the slope of the straight line and given by

- (A) Half coefficient $R_H = \dots\dots \text{ ohm } \dots M^3/\text{weber}$
 (B) No. of charge carriers/ $m^3 = \dots$
 (C) Hall angle $= \dots \text{ Radians}$
 (D) Mobility $m_\mu = \dots \text{ radians } m^2/wb$

	Precautions.
1.	Since hall voltage developed is very small, so it should be measured very carefully and the millivoltmeter used should be quite sensitive.
2.	In finding R_H from relation $R_H = \frac{V_H}{I_x} \cdot \frac{b}{B_z}$ The variations of V_H w.r.t. I_x should be preferred over variation of V_H w.r.t. B_z as it is difficult to measure B_z very accurately.
3.	Find the resistance of the specimen for various values of magnetic fields using the relation $R = V_x/I_x$ as the resistance of the specimen changes with the variation of applied magnetic field due to the variation of mobility of the charge carriers.

SPACE USED FOR STUDENTS WORK AREA

REST OF THE EXPERIMENTS ARE IN PART-II

EXPERIMENT 7

AIM : To find the co-efficient of thermal conductivity of a bad conductor by Lee's method.

APPARATUS USED : Lee's disc apparatus, two $1/10^{\circ}\text{C}$ thermometers, circular disc of the specimen of a bad conductor, (ebonite or card board), a stop watch, a screw gauge, vernier calipers etc.

THEORY : On passing steam through the cylindrical vessel a steady state is reached soon. In this condition the rate at which heat is conducted across the specimen disc is equal to the rate at which heat is emitted through the exposed surface of the lower disc. If K is the co-efficient of thermal conductivity of the material of bad conductor, d its thickness and r its radius; θ_1 and θ_2 the constant readings of the thermometers T_1 and T_2 in the steady state, then rate at which heat is conducted across the disc of the material

$$Q = K \frac{\pi r^2 (\theta_1 - \theta_2)}{d}$$

If M is the mass of the metal disc, s the specific heat of its material, then rate of cooling at θ_2 is equal to

$$= Ms \frac{d\theta}{dt}$$

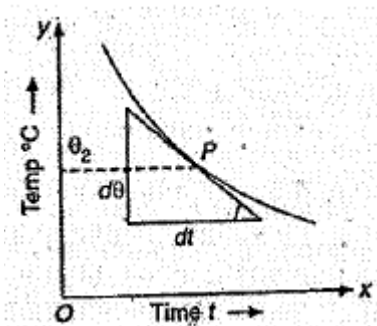
Where $\frac{d\theta}{dt}$ is the rate of fall of temperature at θ_2

$$\frac{K\pi r^2 (\theta_1 - \theta_2)}{d} = Ms \frac{d\theta}{dt}$$

Or
$$K = \frac{Ms d}{\pi r^2 (\theta_1 - \theta_2)} \frac{d\theta}{dt}$$

The rate of cooling is found by heating the metal disc to a temperature about 10°C above the steady temperature θ_2 , it is then allowed to cool and temperature is noted after every 30 seconds till the temperature falls to about 10°C below θ_2 . A graph is then plotted between the temperature and time. A tangent is drawn at a point P corresponding to θ_2 . The slope of the tangent gives the

value of $\frac{d\theta}{dt}$ corresponding to temperature θ_2 .



PROCEDURE :

- 1) Set the apparatus so that the flat surface of the disc is horizontal. Insert the disc of the material in between this disc and the cylindrical vessel. Place the thermometers T_1 and T_2 in position.
- 2) Pass steam from the inlet of the cylindrical vessel and wait till the steady state is reached. This will take 30-40 minutes. When the temperatures indicate by the thermometers T_1 and T_2 are steady note down the temperatures. Interchange the thermometers T_1 and T_2 and again note down the temperatures.
- 3) Remove the cylindrical vessel as also the disc of the material and heat the disc A till its temperature is about 10°C above the steady temperature indicated by T_2 . Allow it to cool and note the temperature at intervals of about 30 seconds, till its temperature falls to about 10°C below θ_2 . Plot a graph between temperature and time.
- 4) Measure the diameter of the disc with a vernier calipers along two diameters mutually perpendicular to each other and measure its thickness with a screw gauge at different points. Also Find the mass of the disc when cooled.

OBSERVATIONS :

Mass of the metallic disk $M =$ gm = kg

Specific heat of metal $s =$ kilo/cal/kg

Diameter of the disc = 1. .

Mean diameter $D =$ cm = m

\therefore Radius of the disc $r =$ cm = m

Thickness of the disc = 1....., 2....., 3....., 4.....

Mean thickness = cm = m

Steady temperature of the thermometers

$T_1 =$ (i) (ii)

$T_2 =$ (i) (ii)

Mean temperature $\theta_1 =$ $^\circ\text{C}$

Mean temperature $\theta_2 =$ $^\circ\text{C}$

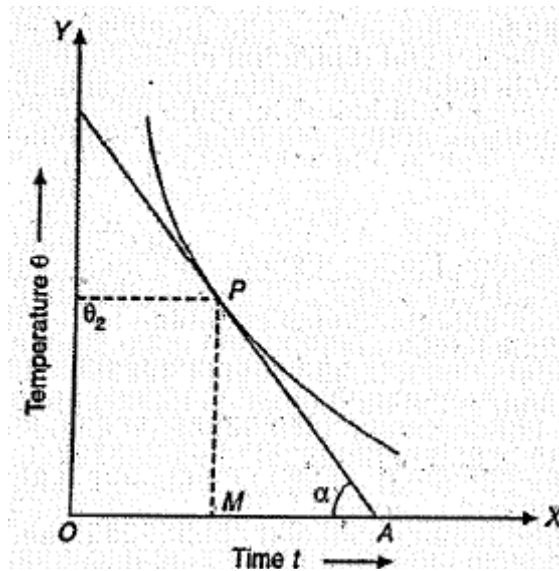
Reading s for cooling curve.

No. of obs.	1	2	3	4	5	6	7	8	9
Time in seconds	30	60	90	120	150	180	210
Temp. of disc									

To find the rate of cooling $\frac{d\theta}{dt}$. Draw a graph taking time t along the X-axis and temperature

θ along the Y-axis. Draw a tangent to the graph at a point P corresponding to the steady temperature θ_2 as shown in Figure 2. cutting the X-axis at A. Draw PM perpendicular to OA.

The rate of fall of temperature $\frac{d\theta}{dt}$ at the temperature θ is given by



$$\frac{d\theta}{dt} = \tan \alpha = \frac{PM}{MA}$$

\therefore Rate of cooling $\frac{d\theta}{dt}$ from the graph corresponding to steady temperature $\theta_2 = \text{ }^\circ\text{C/sec}$.

CALCULATIONS :

$$K = \frac{Msd}{\pi r^2(\theta_1 - \theta_2)} \times \frac{d\theta}{dt}$$

PRECAUTIONS :

1.	Thickness d of the disc of the material should be measured at a number of places on its surface.
2.	The diameter of the disc should be equal to that of the cylindrical vessel and the metallic disc and should be measured in two perpendicular directions.
3.	The thermometers should be placed close to the face of the disc of the specimen.
4.	There should be a good thermal contact between the disc of material and the lower surface of the cylindrical surface and the upper surface of the circular metallic disc. If necessary glycerine may be applied between the surfaces.
5.	The steady state temperatures should be recorded only when the readings of T_1 and T_2 remain constant after an interval of about five minutes.

SPACE FOR STUDENTS WORK AREA

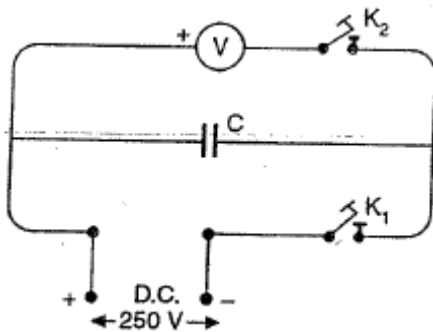
EXPERIMENT 8

AIM : To determine the capacitance of a capacitor by discharging it through voltmeter.

APPARATUS USED : A capacitor of large capacitance more than $64 \mu\text{F}$, a high resistance voltmeter (sensitivity more than 1000 ohm per volt) and range 300 volt, two tap keys, D.C. regulated power supply capable of giving more than 250 volt and a stop-watch.

PROCEDURE :

1) Draw a diagram showing the scheme of connections as in Figure 1 and make connections accordingly.



2) Press the tap key K_1 for some time so that the capacitor is charged to its peak value (say V). Constant potential difference across the two plates of the capacitor C is shown by the voltmeter V when the tap key K_2 is also closed. Note the constant reading of the voltmeter.

3) Keeping the key K_2 closed open the key K_1 and at the same time start the stop watch. As D.C. source is disconnected the capacitor begins to discharge through the voltmeter. Stop the stop-watch as soon as voltmeter shows a drop of 25 volts (i.e., when the voltmeter reads 225 volt). Note the time taken.

4) Recharge the capacitor to the peak value by press again the tap key K_1 . Now note the time taken for the voltmeter across the capacitor to drop to 200 volt (a fall of 50 volt)

5) Repeat the observation by noting the time taken for peak voltage across the capacitor to drop to 175, 150, 125, 100 (steps of 25 volt), 80, 60 (steps of 20 volt), 50, 40, (steps of 10 volt), 25, 20, 15, 10 and 5 (steps of 5 volt).

This is because due to the exponential nature of discharge, voltage drop in the beginning is rapid but with fall in voltage becomes more and more slow. This is why at first the time taken for a voltage drop 25 volt is noted and later on the time for 20, 10 and 5 volt drop respectively is noted.

6) Find the resistance of the voltmeter by half deflection method.

Note. Ordinarily the voltmeter has a resistance of 1000 ohm per volt and a range of 300 volt. Therefore its resistance is about $3 \times 10^5 \text{ ohm} = 0.3 \text{ meg ohm}$. The shunt resistance box should be able to give a resistance of that order. A resistance box with resistance plugs of 100, 200, 200, 500, 1000, 2000, 2000, 5000, 10000, 20000, 20000, 50000 ohm and 0.1, 0.2, 0.2 and 0.5 meg ohm will serve the purpose.

OBSERVATIONS :

Sl.No.	Voltage V	Log _e V	Time t	Sl.No.	Voltage V	Log _e V	Time t
	250				50		
		
				30		
	125				25		
	100				...		
		
	60				5		

Sl.No.	Reading of voltmeter		Shunt resist.	Resistance of voltmeter
	Without shunt	With shunt		

Mean resistance of the voltmeter R = ohm

7) (i) Draw a graph between voltage across the capacitor (V) and time (t), (ii) Also draw a graph between (log_e V) and time t.

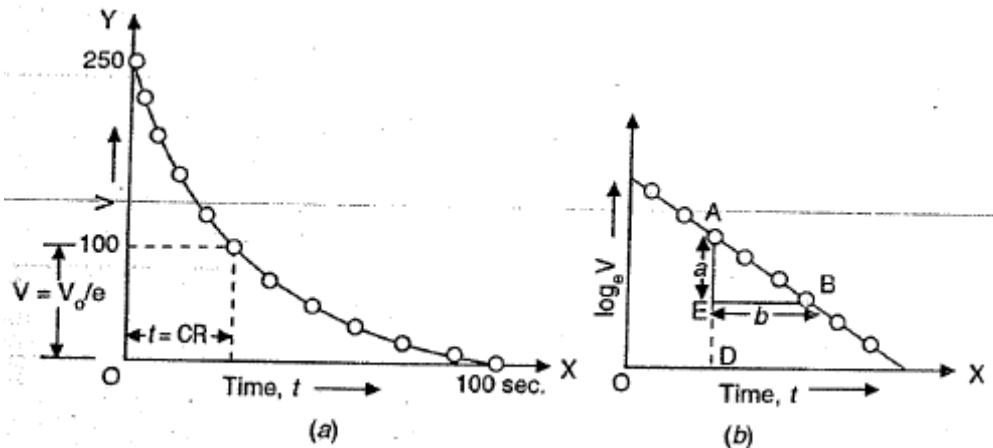


Figure 1

CALCULATIONS :

(i) $V_0 = v_0pt$

$$\frac{V_0}{e} = .368 V_0 = \text{ volt}$$

From graph (i) $t = \text{ sec}$

Resistance of the voltmeter $R = \text{ ohm}$

$$\therefore C = \frac{t}{R} = \text{ Farad}$$

$$= \mu \text{ F}$$

Select two points A and B on the graph (Figure 1) (b) far apart. From A draw AD perpendicular on X-axis and from B draw BE perpendicular on AD. Measure AE = a and BE = b

Slope of the graph = $-\frac{a}{b} =$

$$\therefore C = - \frac{1}{R \times \text{slope of the graph}}$$

$$= \frac{-1}{R \times \left(-\frac{a}{b}\right)} = \text{ Farad} = \mu \text{ F}$$

PRECAUTIONS :

Peak voltage should be noted when both the keys K_1 and K_2 are pressed.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 9

AIM : Find the internal resistance of leclanche cell using a potentiometer.

Apparatus: A potentiometer, a battery, leclanche cell, two one way keys, a sensitive galvanometer, rheostat, two resistance boxes, jockey, an ammeter, a voltmeter, connection wires, sand paper etc.

Theory. Let the p.d. across the terminals of the cell when no current is drawn from it be E and the p.d. when it sends a current to the resistance S be V , then we have

Internal resistance of the cell

$$r = \frac{E - V}{V} \times S$$

The values of E and V are determined I in terms of the length of the potentiometer wire,
 Let l_1 is the length of the wire to the point where a balance point is got in an open circuit, then

$$V = \rho.I.l_2$$

We have the relation $r = \frac{E - V}{V} \times S$

$$r = \frac{l_1 - l_2}{l_2} \times S$$

Knowing l_1 , l_2 and S the internal resistance of the cell can be found.

Procedure

Draw diagram showing the scheme of connection Figure (1) and make the connections accordingly. Take out 5000 R from resistance box R.

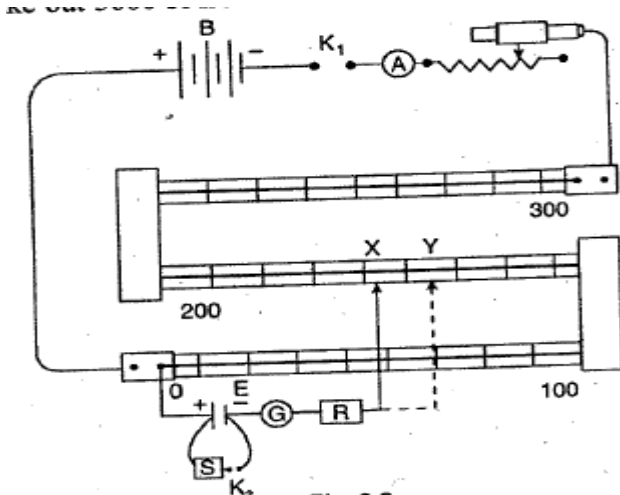


Figure (1)

2. To test the connections. Introduce the plug in the key K1 and keep K2 open. Press the jockey at the zero end and note the direction of deflection.

Now put the jockey at the other end, if the direction of deflection opposition to that in the first case, the connections are correct. If the direction of deflection is the same, then increase the current in the main circuit till the deflection in the second case is reversed.

3(a) Move the jockey along the wire to find a point where the galvanometer gives zero. Insert the 5000 ohms plug and find the null point accurately as at X. Note that length l_1 of the wire and the current in the ammeter. Put in the key K₂ and take out 1 ohm plug from the resistance box S and make all other plugs tight. Find the balance point again as at Y and note the corresponding length l_2 . Repeat twice for the same value of the current in the auxiliary circuit and same shunt resistance in a similar manner to avoid any error.

(b) Put the plugs from the keys K_1 and K_2 . Wait for some time, put the plug in the key K_1 and find l_1 keeping the current same in a similar manner. Put in the plug in the key K_2 , take out a resistance of 2, 3, 4 ohms and find the length l_1 in each case.

4. Take similar reading by varying the current in the main current.

Observations

S.No.	Ammeter reading	Position of null point							
		Without shunt			With shunt				
		(a)	(b)	Mean l_1	(a)	(b)	Mean l_2		
1									
2									
3									
1									
2									
3									

Precautions

1. The e.m.f of the auxillary batter should be constant and always more than the e.m.f of the cell, whose internal resistance is to be found out.

2. The positive pole of the battery and the positive pole of the cell must be connected to the terminal on the zero side of the potentiometer wire.

3. The rheostat should be of a low resistance and the current must be changed to get the nill point at a desired length.

The current should remain constant for each of readings.

4. The current should be passé donly for the duration it is necessary, otherwise the balance point will go vary.

The internal resistance of a Leclanche cell is not constant but increases with the current drawn from the cell. So to get concordant readings the resistance form the resistance box S must be changed by a small amount.

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 10

AIM : To draw the V-I characteristics of a forward and reverse bias junction diode and to draw the load line

APPARATUS USED : A junction diode [BY 127], millimeter (0-500 mA), voltmeter (0 – 3 V), battery, key, rheostat, micro-ammeter (0-100 μ A), voltmeter (0-100V), a D.C. power supply c of giving about 100 volt supply.

PROCEDURE (i) Forward bias characteristics.

1. Draw a diagram showing the scheme of a function as in Figure 1 and make connections accordingly.

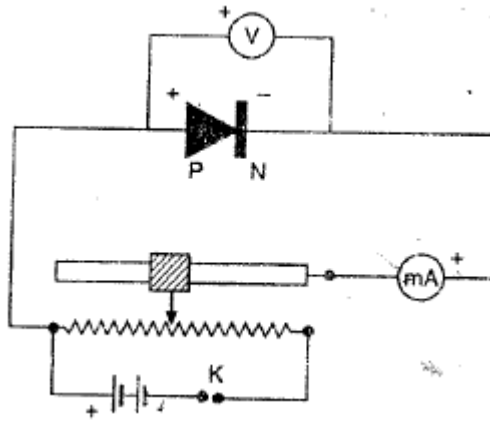


Figure - 1

2. Adjust the position of the variable contact of the rheostat so that the voltmeter reads zero, increase the voltage in steps of 0.2 volt and note the voltmeter as well as the correspondence millimeter reading for each setting upto the full range of the battery.

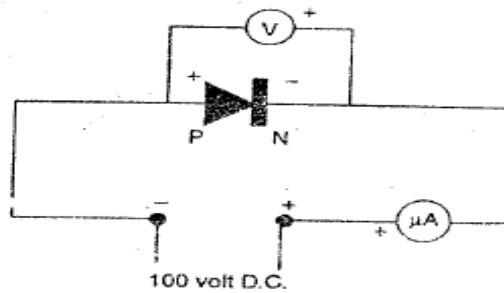


Figure - 2

(ii) Reverse bias characteristics. 1. Draw a diagram showing the scheme of connections figure 2 and make connections accordingly. Starting from zero volt first increase the voltage in of one volt and then in steps of 5 volt. Note the corresponding current in micro-ammeter. D graph between voltage and current taking the voltage for forward bias along the +X-axis and along +Y-axis and for reverse bias the voltage along the - X-axis and current along - Y-axis. A graph is shown in figure (4)

Observations				
S.No.	Forward bias		Reverse bias	
	Voltmeter reading	Current in mA	Voltmeter reading	Current in mA

Precautions

1. In a forward bias characteristic the position of the rheostat should be add.... so that the voltmeter reading is zero. The voltage then should be increased in steps of 0.2 voltmeter.
2. In reverse bias characteristics, the voltage should be increased in steps of 1 volt starting from reading int eh beginning and then in steps of 5 volt.

3. ... Load line a diode-circuit. Consider the circuit shown in Figure (3) where the diode is based by a source of voltage V. If the source has a negligible (zero) resistance $V = V + IR_L$
 V_o is the voltage drop across the diode, I the cuurent through the circuit and R_L the load
 Distance

$$I = \frac{1}{R_L} V_D + \frac{V}{R_L} \dots\dots\dots(i)$$

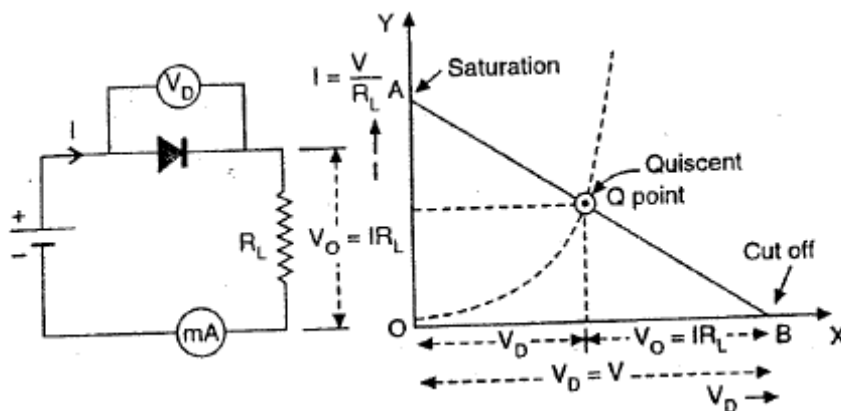


Figure – (3)

4. This is an equation of the type $y = mx + c$ the equation of a straight line. Hence a graph between along the Y-axis and V_D taken along the X-axis is a straight line.

If $V_D = 0$ the, $I = \frac{V}{R_L}$

This gives the point A on the I or Y-axis and represents the maximum value of the current called function current $I = \frac{V}{R_L}$

If $I = 0$ $V_D = V$

This gives the point B on the V_D or X-axis and represents the maximum value of V_D corresponding to zero current called the cut off voltage.

The straight line joining AB is called the load-line.

If we draw a forward bias static characteristics of the diode also alongwith the load line, then the intersection of the static characteristics curve with the load-lien gives the operating point or

Quiescent point Q. The point Q represents the current through the load resistance R_L and the corresponding value of V_D the voltage drop across the diode.

To draw the load line. To find the point A, short circuit the diode so the $I = \frac{V}{R_L}$ and measure the current. To find the point B measure the voltage across the source in open circuit. Join the point A and B, then AB is the load line.

Figure (1) Zener diode. A Zener diode is a silicon crystal diode which conducts in the reverse direction at a certain fixed voltage. It is a highly doped, P-N junction having a high back resistance.

As show in in Figure (4), it is found that when a reverse bias is applied to a crystal diode a very small reverse current (known as leakage current) flows due to high reverse resistance. As the value of the reverse bias is increased, a small current due to minority carriers flows in the circuit. As the reverse bias is increased further, a stage reaches when the applied field is so high that a large number of co-valent bonds are broken with consequent abrupt increase in current. Further, the electrons are also accelerated to high velocities due to the large field and bring about ionization by collision at most of the crystal. The electrons ... produced are again

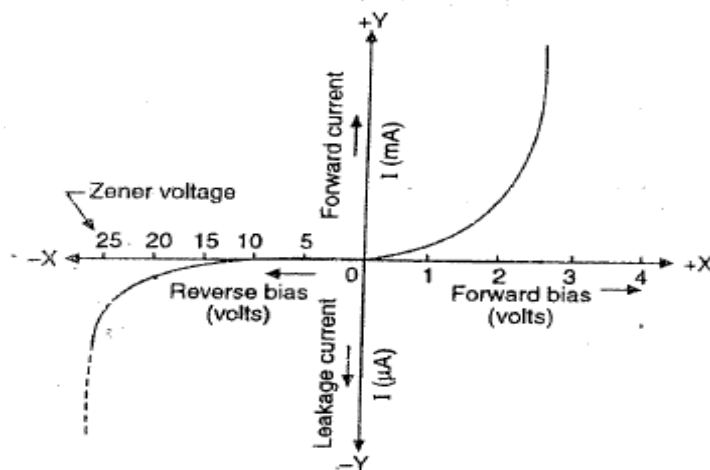


Figure – (4)

Accelerated produce more free electrons due to there ionization (by collision). The process is known as avalanche process and gives rise to a very large currer.. the diode and the junction is said have a breakdown.

The value of reverse voltage which breakdown occurs is called breakdown voltage or Zner voltage.

Due to the large increase in current the back resistance drops to a very low value. After the breakdown has current the voltage across the junction remains constant over a fairly with range.

A Zener diode can be used a Voltage – regulator to provide a constant voltage from a source whose voltage may vary over a sufficient range. The Zener voltage depends upon the semi-conductor material, amount of doping and method of producing the P-N junction. Zener diodes can be obtained with breakdown voltage ranging from 2 volt to several hundred volts by adjusting the concentration of the impurity in the materials producing the P-N junction.

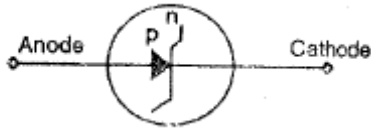


Figure - (5)

A zener diode is symbolically represented as in Figure (5)

Voltage regulation characteristics: The basic Zener diode D.C. voltage regulation circ is shown in figure – (6)

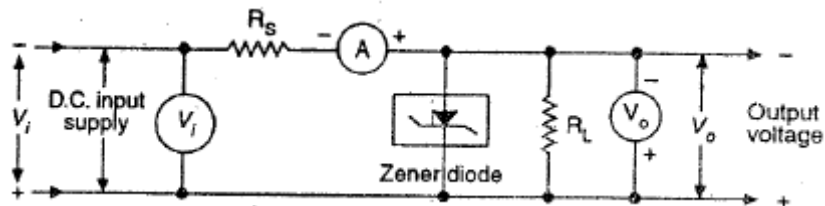


Figure – (6)

The Zener diode with Zener voltage V_Z is connected in parallel with the load resistance R_L at which a constant output voltage is desired. The Zener diode is reverse biased with output voltage whose variations are to be regulated. It will maintain a constant output voltage $V_O = V_Z$ across the as long as the input voltage does not fall below V_Z . When the input voltage V_i is greater than V_Z large current I_Z will flow through the Zener diode and the series resistance R_S and the voltage or across R_s will increase maintaining the voltage drop across R_L at constant value $V_O = V_Z$.

When the input voltage is less than the breakdown (or zener voltage) very small current flow through the Zener diode and the whole input appears across the output terminals. Consequently with this range the output voltage increases linearly with the input voltage. The voltage regular characteristics curve of Zener diode is shown in Figure 7(a)

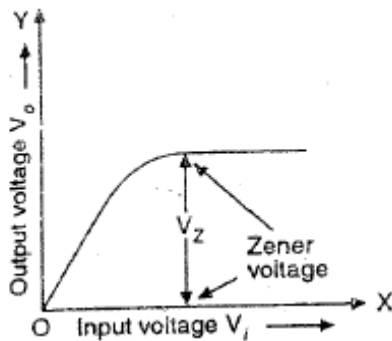


Figure 7(a)

Semiconductor Diode

..... Study the voltage regulation property of Zener diode with load resistance R_L , the input is at a value greater than the zener voltage for the given diode. On gradually increasing the

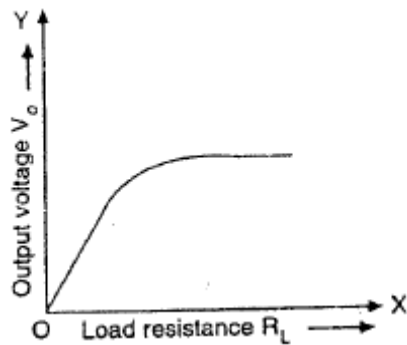


Figure 7(b)

Resistance it is found that for small values of load resistance the output voltage increases linearly Load. For large values of load resistance the output voltage remains constant. The variation of voltage with load resistance is shown in Figure 7(b).

To study Zener diode voltage regulating characteristics.

Apparatus. A variable D.C. supply, a Zener diode, voltmeter and an ammeter with ranges coding to zener diode supplied, tow resistance boxes R_S and R_L , connecting wires etc.

PROCEDURE

1. Draw a diagram showing the scheme of connections as in Figure 6 and make sections accordingly.

Note: The Zener diode must be connected in reverse bias.

2. Introduce a fixed resistance R_S (100 to 500 Ω) in series with the diode. Keep it constant throughout the experiment. Introduce a load resistance R_L of about 1000 ohm.
3. Starting from very low values of input voltage increase it in small steps well above the zener voltage for the given diode. For each observation note the input voltage V_i and corresponding output voltage V_o . Also note the current in the input circuit.
4. Plot a graph between input voltage V_i taken along the X-axis and output voltage V_o taken along Y-axis. The graph is as shown in figure 7(a).
5. **Voltage regulation with load.** Keep the input voltage at a value more than the zener voltage. Starting from a small value of about 50 ohm for R_L , increase it in steps of 50-100 ohm. Note the distance and the corresponding values of output voltage.
6. Plot a graph between load resistance R_L taken along the X-axis and output voltage V_o taken Y-axis.. The graph is as shown in figure 7(b).

Observations

Series resistance R_S = ohm			
Load resistance R_L = ohm			
Sl.No.	Input Voltage V_i	Current	Output voltage V_o
	0 V		
	0.5 V		
	1.0 V		
	.		
	.		
	.		
	.		

SPACE FOR STUDENTS WORK AREA

EXPERIMENT 11

AIM : To find the value of Planck's constant and photo electric work function of the wall of the cathode using a photo-electric cell.

APPARATUS USED : A vacuum type photo-cell enclosed in tight box; (R, C, A. 935 or its equivalent), 6 volt supply, a voltmeter (0-3 volt capable of reading up to 3 volt), a rheostat, a moving coil reflecting type galvanometer with lamp and scale arrangement, Key, a mercury lamp, light filters (red, yellow, green, blue, violet)

THEORY : Photo-electric effect. It is a phenomenon of emission of electrons from a metal surface when light of suitable wavelength falls on it. The electrons emitted are known as photo electrons. Some metals like sodium, potassium and caesium emit electrons even when visible light falls on them whereas zinc, cadmium etc. are sensitive only to ultra – violet light. Light of shorter wavelength is effective in producing photo-electrons than light of longer wavelength. The effect

is also ... in non-metals but as these are highly electro-negative light of very short wavelength is red for the purpose.

Laws of photo-electric emission.

- 1) The emission of photo-electrons take place only when frequency of incident radiation is above a certain critical value characteristics of that metal. The all value is known as Threshold frequency for the metal.
- 2) The emission of photo-electrons takes place as soon as light falls on the metal surface i.e. is no time-lag between the incidence of photon and emission of electron.
- 3) The maximum kinetic energy with which an electron is emitted from a metal surface is Of the intensity of incident light but depends only upon its frequency.
- 4) The number of photo-electrons emitted i.e. photo-electric current is independent of frequency of incident light but only depends upon its intensity.

Photoelectric cell. A photo-electric cell is an arrangement to convert light energy into Energy.

According to their constructing the photo-electric cells are of three types.

- (i) Photo-emissive cell, (ii) Photo-conductive cell and (iii) Photo voltaic cell

i) Photo emissive cell. There are two types of photo emissive cells

- (i) Vacuum type and
- (ii) Gas filled type

A vacuum type photo electric (emissive) cell consists of a glass or a quartz bulb trading as it is to be used with visible or ultra violet light. It consists of a cathode C use from of a semi cylindrical plate having a large surface area and an anode A in from of a straight wire or a wire frame as show in Figure 3. When the cell is to be used with visible light a sensitive material like sodium, potassium or caesium is posited on the cathode. For use with ultra violet light the material used is cadmium. To have a large number of electrons per photon of light, composite materials such caesium on silver oxide (Ag – O – Cs) or antimony caesium alloy (Sb – Cs) or a gently developed combination of bismuth, silver, oxygen and caesium (Bi – Ag – O – Cs) are used photo-cathode materials.

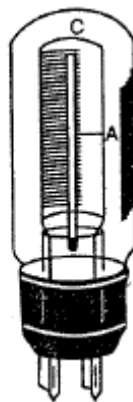
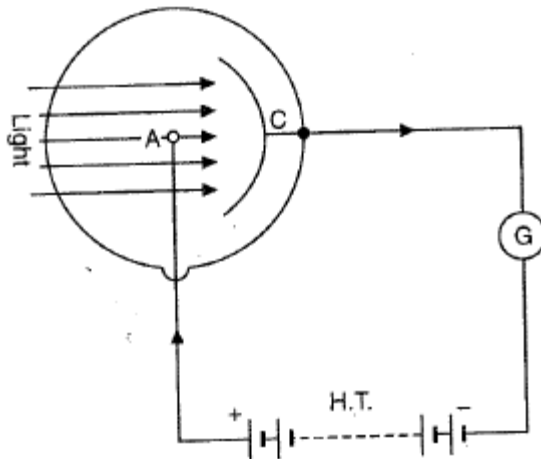


Figure 1

The current in a vacuum type (emissive) cell is small. To increase the current the cell is filled with an inert gas like neon or argon at a pressure of a few millimeter of mercury. Such a cell is known as a gas-filled cell.



A simple circuit showing the working of a photoelectric cell is shown in figure 1. If a light of suitable wavelength is allowed to fall on the cathode C it gives out electrons. When the anode A is maintained at a positive potential the electrons are attracted towards it ... Conventional current flows in the external circuit shown. If A is maintained at a negative potential electrons are repelled by it and a smaller number ... reaches it. The current, therefore, decreases and at a certain negative potential no photo electrons reach the anode. This potential is called stopping potential or cut-off voltage.

If V_s is the stopping potential, m , e and v_m mass, charge and maximum velocity of the ejected electrons respectively, then

$$V_s e = \frac{1}{2} m v_m^2$$

Or

$$v_m = \sqrt{\frac{2V_s e}{m}}$$

The velocity of ejected electrons increases with increase in frequencies of the incident light, the frequency is below a certain critical value called threshold frequency no electrons are ejected. If ν_0 is the threshold frequency the energy required to eject the electrons just out of the surface given by

$$\omega_0 = h\nu_0$$

Where ω_0 is known as photo electric work function.

In photo electric effect all or none of the energy of the incident photon is transferred to an electron in the metal. If, therefore, light of frequency $\nu > \nu_0$ falls on the photo-sensitive metal part of the photo-cell the energy of the incident photon is used by the electron to come out of the metal (photo-electric work function) and the rest is stored in it as kinetic energy.

$$\begin{aligned} \therefore h\nu &= \frac{1}{2} m v_m^2 + \omega_0 \\ &= V_s e + h\nu_0 \end{aligned}$$

Or
$$V_s = \frac{h}{e} \nu - \frac{h}{e} \nu_0$$

Thus a graph between stopping potential V_s and frequency of incident light ν is a straight. The slope of the straight line

$$\tan \theta = \frac{h}{e}$$

Or
$$h = e \tan \theta$$

$$= e \frac{\Delta V_s}{\Delta \nu}$$

PROCEDURE :

1) Draw a diagram showing the scheme of connections in figure 1 and connectivity. Arrange the mercury lamp and the photo-cell as shown and set up the lamp and scale measurement of the galvanometer so that the spot of light moves freely on the scale.

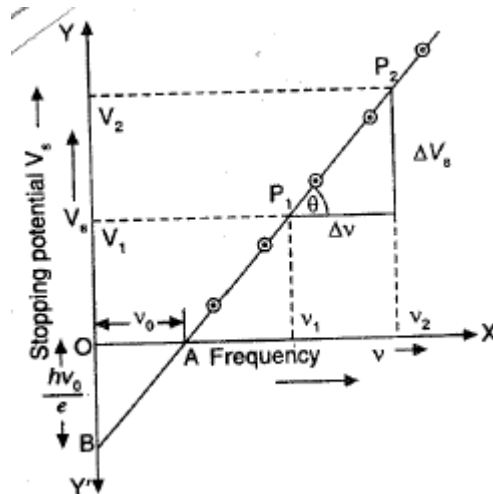


Figure - 2

With the box closed (no light falling on the photo-cell) adjust the sliding contact to the extreme point P so that when the key K is introduced the voltmeter reads zero. Adjust the position of the galvanometer scale so that the spot of light with its central cross-wire is at zero graduation.

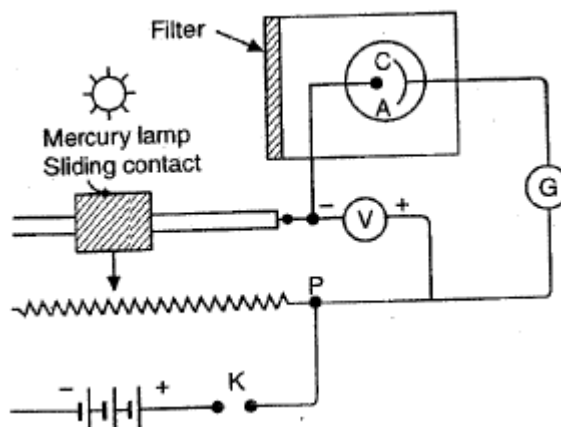


Figure 3

Place the violet filter ($\lambda = 4050 \text{ \AA}$) in front of the photo cell and switch on the mercury vapour lamp. Adjust the distance of the lamp so as to get a reasonable deflection on the galvanometer scale. Note the reading of spot of light on the scale and also that of the voltmeter.

2) Slowly move the sliding contact towards Q (negative end of the battery) so that a negative potential of 0.05 V is applied to the anode A of the photo-electric cell. The deflection will slightly decrease. Note the scale reading and meter reading. Go on increasing the negative potential applied to the anode A in steps of 0.05 volt on noting the voltmeter reading and corresponding scale reading until the spot of light returns to position. Take at least three more readings by further increasing the negative potential in steps 05 volt.

3) Repeat the experiment with blue ($\lambda = 4360 \text{ \AA}$), green ($\lambda = 5780 \text{ \AA}$) and red ($\lambda = 6910 \text{ \AA}$) Filters.

Sl. No.	Voltmeter reading (Negative)	Scale deflection with				
		Violet filter	Blue filter	Green filter	Yellow filter	Red filter
	0 volt					
	-0.05					
	-0.10					
	-0.15					
					
					

5) For each filter draw a graph between voltmeter reading (negative anode voltage) and deflecting in cm. From the graph, find the value of stopping potential V_1 for which scale deflection is zero corresponding to each wavelength and record.

Note. Alternatively the value of stopping potential corresponding to each filter may be form directly without plotting the graph. For this purpose the negative potential applied to the anode of photo-cell is increased very slowly so that the deflection on the galvanometer scale just becomes zero. The corresponding voltmeter reading gives the stopping potential for each filter.

Filter	Violet	Blue	Green	Yellow	Red
Wavelength λ	$4050 \times 10^{-10} \text{ m}$	$4360 \times 10^{-10} \text{ m}$	$5460 \times 10^{-10} \text{ m}$	$5780 \times 10^{-10} \text{ m}$	$6910 \times 10^{-10} \text{ m}$
Frequency $V = \frac{c}{\lambda}$					
Stopping pot V_s					

6) Plot a graph between stopping potential V_s taken along the Y-axis and corresponding frequency ν taken along the X-axis. The graph is a straight line as show in Figure 3. Take two points P_1 and P_2 sufficiently apart on the straight line. Find the values of stopping potentials V_1 and V_2 frequencies ν_1 and ν_2 corresponding to P_1 and P_2 .

$$\text{Slope of the graph} = \tan \theta = \frac{V_2 - V_1}{\nu_2 - \nu_1} = \frac{\Delta V_s}{\Delta \nu} = \text{volt sec}$$

$$\text{Now} \quad e = 1.59 \times 10^{-19} \text{ C}$$

$$\therefore \text{Plank's constant } h = e \tan \theta$$

$$= e \frac{\Delta V_s}{\Delta \nu} = 1.59 \times 10^{-19} \times \frac{\Delta V_s}{\Delta \nu}$$

$$= \text{Joule sec.}$$

Threshold frequency (corresponding to point A) $\nu_0 =$

Photo-electric work function $w_0 = h\nu_0 = \text{Joule}$

Photo-electric work function (corresponding to point B)

$$= \text{OB electron volt}$$

PRECAUTIONS :

- 1) While adjusting the galvanometer reading at zero mark and voltmeter reading 0 volt, no light should fall on the photo-cell .
- 2) The distance between the mercury lamp and the photo-cell should be kept constant during experiment .

SPACE FOR STUDENTS WORK AREA