B. L. D. E. Association's

# *S. B. Arts and K. C. P. Science College, Vijayapur*

## Department of PG Studies in PHYSICS

# Laboratory Manuals

B. L. D. E. ASSOCIATION's

S. B. ARTS AND K. C. P. SCIENCE COLLEGE, VIJAYAPUR

Department of PG Studies in PHYSICS

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**M. Sc. Physics 1st Semester**

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**Department of PG Studies in PHYSICS**

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**M. Sc. Physics 3rd Semester**

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## S. B. ARTS AND K. C. P. SCIENCE COLLEGE, VIJAYAPUR

### Department of PG Studies in PHYSICS

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**M. Sc. Physics 4th Semester**

# Experiment No: 1
# HALL EFFECT

**Aim:** Using Hall Effect set up to study the following for a given semiconductor specimen.

- **a.** To determine Hall Coefficient and type of Carrier.
- **b.** To determine Carrier Concentration of the specimen.
- **c.** To determine Hall Mobility of Charge Carrier.
- **d.** To determine the relaxation time.

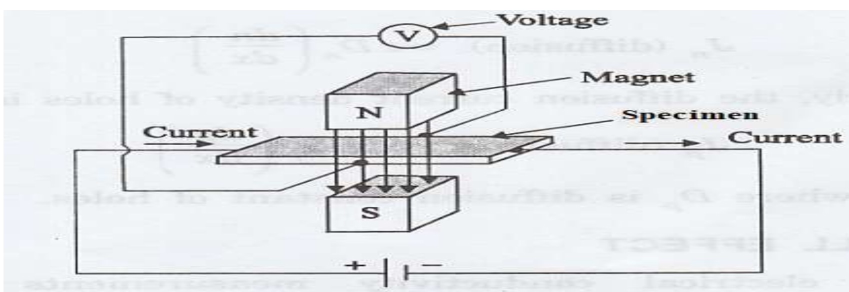
**Apparatus:** Hall Effect set up, Constant current power supply, Gauss meter with probe, multipurpose stand, electromagnet, semiconductor specimen, digital milivoltmeter.

**Formula:**

- **a.** Hall Coefficient $R_H = Z/B\ V_H$ (in Ωm/T)
- **b.** Carrier density or Charge Concentration $n = 3\pi/8eR_H$ (in $m^{-1}$)
- **c.** Hall mobility or Carrier mobility $\mu = 8/3\pi\sigma R_H = 8/3\pi R_H\ 1/$ ʄ (in $cm^{-2}s$)
- **d.** Relaxation time, $\tau = \mu m/e$ (in s)

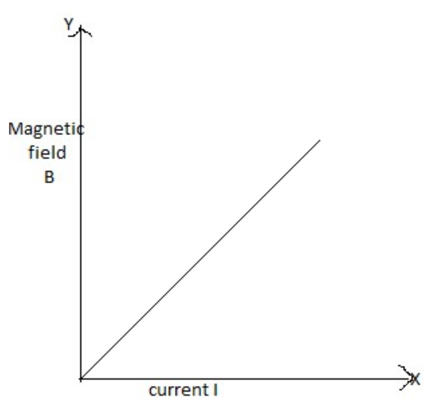
Where, $V_H$ – Hall Voltage (in volts)
e- Charge on electron (in c)
I- Current applied (in A)
m- Mass of electron (in kg)
b- Breadth of Specimen (in m)
B- Magnetic field (in T)
l- length of Specimen (in m)
Z-Thickness of specimen (in m)

**Circuit Diagram:**

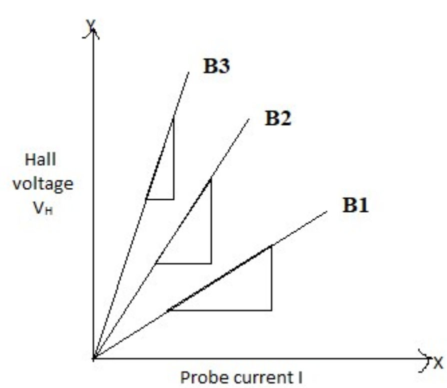



**Nature of graph:**

Calibration of Magnets




Determination of Hall Coefficients



**Observation:**

- **a)** Specimen=____________mm=__________m
- **b)** Thickness of specimen(Z)=___________mm=__________m
- **c)** Length of Specimen(l)=___________mm=__________m
- **d)** Breadth of specimen(b)=________mm=__________m
- **e)** Charge of electron (e)=__________Coulomb
- **f)** Mass of electron (m)=___________kg

**Tabulation:**

**1) For calibration of Magnets (1G=$10^{-4}$T)**

| Current I in mA | Magnetic flux B | |
|---|---|---|
| | B (in Gauss) | B (in Tesla) |
| | | |

**2) Determination of Hall Coefficients**

| Probe current I | Voltage (in mv) | | | | Hall voltage $V_H$ | | |
|---|---|---|---|---|---|---|---|
| | Without field V (in mv) | With field $B_1$ | $B_2$ | $B_3$ | $V_{H1}$ V~$V_1$ | $V_{H2}$ V~$V_2$ | $V_{H3}$ V~$V_3$ |
| | | | | | | | |

**Calculation:**

Hall Coefficients $R_H$= $ZV_H$/bI =Z/b X Slope

$R_H$= $R_H$+$R_H$+$R_H$/3

Type of Semiconductor = ____________

**Result:**

# Experiment No: 2
# FERMI ENERGY

**Aim:** To determine the Fermi energy and Fermi Temperature.

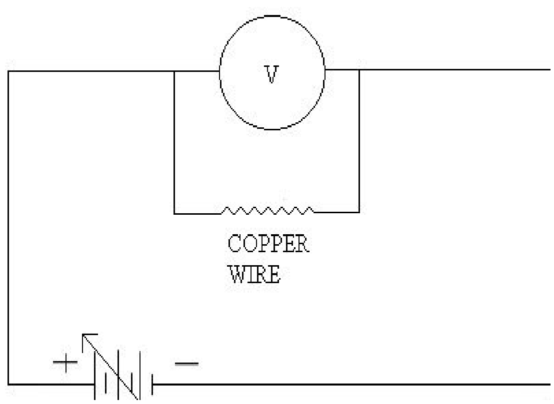
**Apparatus:** D.C regulated power supply, Thermometer, Connection wire etc.

**Formula:**

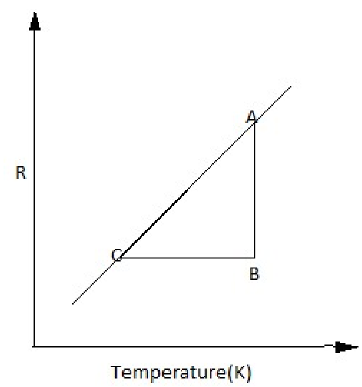
- Fermi Energy, $E_F = \left[\frac{ne^2\pi Ar^2}{L\sqrt{2m}}\right] X \left[\frac{\Delta R}{\Delta T}\right]^2$
- Fermi Temperature, $T_F = \frac{E_F}{k_B}$

Where, $\mathbf{E_F}$ – Fermi energy
**n**- Electron density
**e**- Charge of electron
**A**- Constant
**r**- Radius of copper
**L**- Length of Copper
**m**- Mass of Electron
**k**- Boltzmann's constant

**Circuit Diagram:**




**Nature of graph:**




**Observations and Tabulation:**

Metal Wire used: _______________

Length of wire **L=2.2m**

Radius $\mathbf{r=0.165x10^{-3}}$ **m**

Density **ƒ=8930 kgm**$^{-3}$

Mass of wire **M= 63.54gm**

Cross selection area $\Pi r^2$**= 85.52x10**$^{-9}$**m**$^2$

Avogadro's number **N= 6.023x10**$^{26}$

Constant **A= 11.57x10**$^{-6}$

Charge of Electron **e=1.602x10**$^{-19}$ **C**

Mass of Electron **m=9.1x10**$^{-31}$

Electron Density **n=8.4 6 4x10**$^{28}$

**(Heating or Cooling))**

| Temperature | | Voltage(in mV) | Current (in mA) | Resistance (in Ω) |
|---|---|---|---|---|
| (in $^0$C) | (in K | | | |
| | | | | |

**Procedure and Precautions in handling the experimental setup:**

1. About 2 meter length copper wire is taken and its radius is determined and cross sectional area is calculated. Its mass number and density are noted from Clark's table.
   $L_{Copper}$=2.2meter, radius r=0.165x10$^{-3}$m
   Cross sectional area = $\Pi r^2$ =85.52x10$^{-9}$m$^2$
   Density ƒ=8930 kgm$^{-3}$
   Mass nuclear M= 63.54gm

2. The wire is wound over an insulating tube (10-15mm diameter) to form a coil. The coil is immersed in pre heated liquid paraffin as shown in experimental set up. The two end of the coiled wire is connected to a power supply through a mill ammeter.And millivolt meter is connect across the coil.
3. A thermometer is immersed in the beaker containing liquid paraffin and coil. When the thermometer attains steady temperature the temperature is noted.
4. The power supply is switched on and voltage and currents are noted. The liquid is allowed to cool and power supply is switched off until another steady temperature is reached.
5. Trail is repeated taking reading in the interval of 5 degree and until the temperature reach 45degree. At each temperature the voltages and currents measured are noted.
6. A graph is draw n taking temperature in degree K along X-axis and resistance on Y axis as shown. The slope of straight line is calculated.
7. Experimental is repeated for Iron, silver and Gold wires.

**Result:**

Fermi Energy $E_F$= ___________________J
Fermi Temperature $T_F$ = ____________K

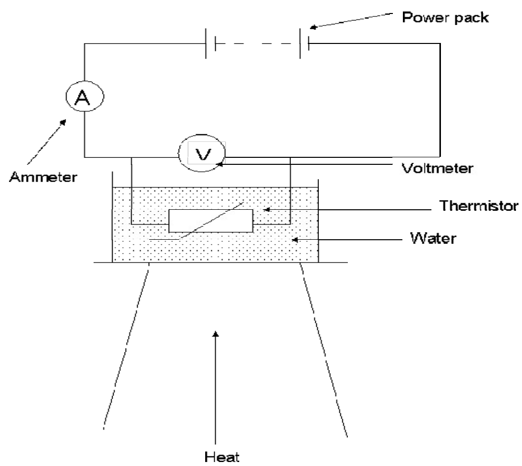
# Experiment No: 3
# Energy gap determination using Thermistor

**Aim:** Thermistor Characteristics and its energy gap determination.
**Apparatus:** Thermistor kit, Connecting wires, Thermometer etc.
**Formula:**

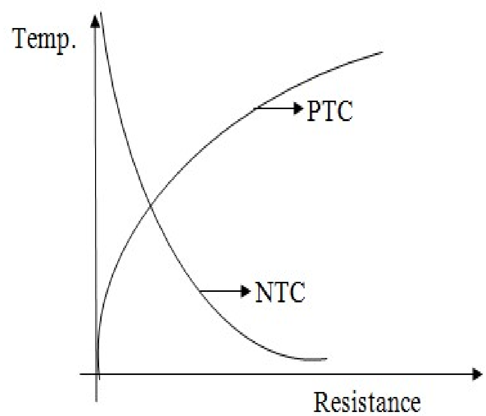
Energy gap $E_g = 2k_B T \ln R = 2k_B \frac{\ln R}{1/T} = 2k_B$ (slope)

Where, $K_B$= Boltzmann Constant
T =Temperature
R= Resistance

**Circuit Diagram:**




**Nature of graph:**




**Observation and Tabulation:**
Room temperature, **T**=______ **$^0$C = _________ K**
Boltzmann's Constant, $\mathbf{k_B}$=8.862X10$^{-5}$eV/K
Voltage **V**=____________V

**(Heating and Cooling)**

| Sl. No. | Temperature (in$^0$C) | Temperature (in K) | 1/T (in $K^{-1}$) | Voltage (in V) | Current (in I) | R=V/I | lnR |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

**Procedure and Precautions in handling the experimental setup:**

1. The three resistor materials are identified. Their resistance are measured at the room temperature using a DMM and are recorded.
2. The three resistors are connected to the terminals through the selector switch(two pole -3 way slide switch) on the stand, as shown in the apparatus. The DMM is connected

to the socket and the selector switch is thrown to position 1 which measures resistance of the copper wire connected through the selector switch.

3. The selector switch is now thrown to position-2 which selects the thermistor and the DMM measures the resistance of the thermistor.
4. The selector switch is thrown to Position-3 which selects the CFR and the DMM measures the resistance of the CFR. The measured values of resistance of all the three resistors materials at room temperature are tabulated
5. Now the selector switch is positioned at position 1 to measure the resistance of the copper coil. Distilled water is boiled by dipping the coffee heater rod in it and all the three resistors are immersed into the heated distilled water and the digital thermometer is fitted onto the stand to read the water temperature. The steady state temperature is noted and recorded.
6. Resistance values are noted at equal intervals of temperature drop, starting from $93^0$C to the room temperature. The resistance value noted is recorded.
7. The water in the beaker is now replaced by ice cubes and the copper coil is immersed in ice cubes and the steady state temperature and resistance are noted.
8. The graph is drawn taking $R/R_{ref}$ on y-axis and $(T-T_{ref})$ on x-axis. From the straight line graph slope and y-intercept are noted.
9. Experiment is repeated by selecting thermistor by setting the selector switch to position 2.The resistance recorded at various temperatures are tabulated.
10. A Plot shoeing variation of ln(R) with (1/T).From the straight line obtained, its slope is calculated.
11. The energy band gap of the semiconductor, which is smaller than that of germanium. Hence the thermistor material may be a metal oxide.
12. The temperature coefficient of thermistor is not a constant for given sample. It is always specified at a temperature.
13. The 10Ω/2W resistor is now selected by switching switch to position 3. For temperature varying from $93^0$C to $5^0$C resistance is noted and recorded.
14. To compare resistance variations of three different samples with temperature their values are plotted.

**Result:**

Energy gap of given Thermistor is =_________________________eV

# Experiment No: 4
# Plank's Constant

**Aim:** Determination of Plank's Constant using LED's.

**Apparatus:**Battery, Rheostat, plug key, Resistor, Milli ammeter, diode, voltmeter, connecting wire etc.

**Formula:**

**E**=hν

E=hc/λ

$V_{knee}$=hc/λ  h=λ$V_{knee}$/c =__________eVs

h=__________Js

Where, E- Energy

h- Planck's constant

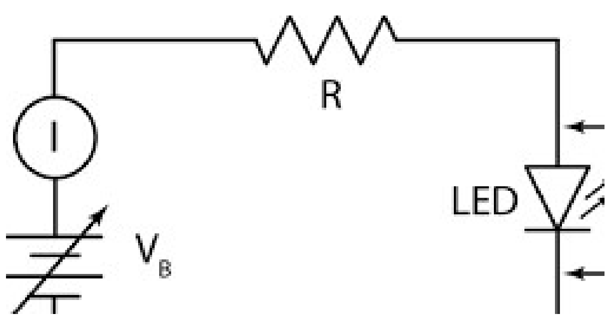
C-Speed of light

$V_{knee}$ – Knee voltage

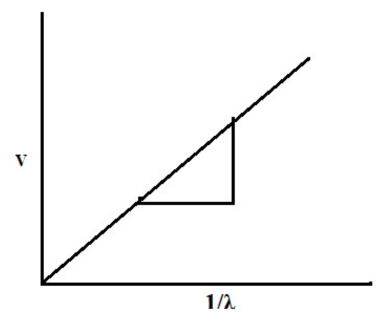
λ – Wavelength of LED

ν – Frequency

**Circuit Diagram:**




**Nature of graph:**




Ba-Battery  Rh-Rheostat

mA –miliammeter  R-Resistor

D-LED  V-voltmeter

**Observation:**

Speed of light C=3X$10^8$m/s

e=1.602X$10^{-19}$C

**Tabular Column:**

| Sl. No. | Colour of LED | Wavelength λ in nm | Knee voltage V(volt) | 1/ λ X$10^{-3}$ | λ V | h=e λ V/C in Js |
|---|---|---|---|---|---|---|
| | | | | | | |

**Result:**

The obtained value for the Planck's constant is________________Js.

## Experiment No. 1
## NUMERICAL APERTURE

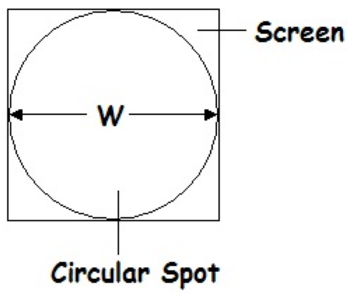
**Aim:** To determine the numerical aperture of given optical fibre.

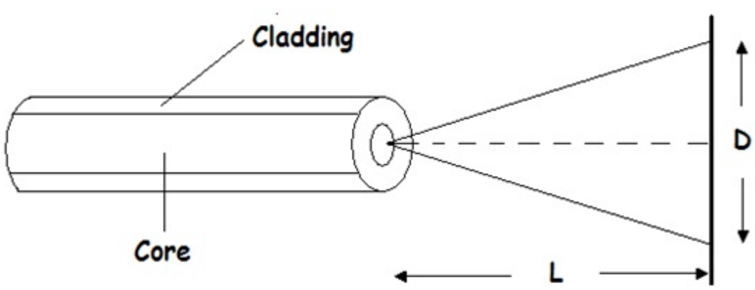
**Apparatus:** Monochromatic source, optical fiber, cable screen pad, distance measuring scale thread etc.

**Formula:**

1) Numerical aperture $NA = D/(4k^2+D^2)^{1/2}$
   Where D is the width or diameter of the red spot on screen.
2) Acceptance angle $\Theta_{max} = \sin^{-1}(NA)$

**Diagram:**




**Tabulation:**

| Sl.No | Distance between screen and end of optical fibre L in cm | Width of spot 'w' in cm | Numerical aperture (NA) | Acceptance angle $\Theta_0=\sin^{-1}(NA)$ in degree |
|---|---|---|---|---|
| | | | | |

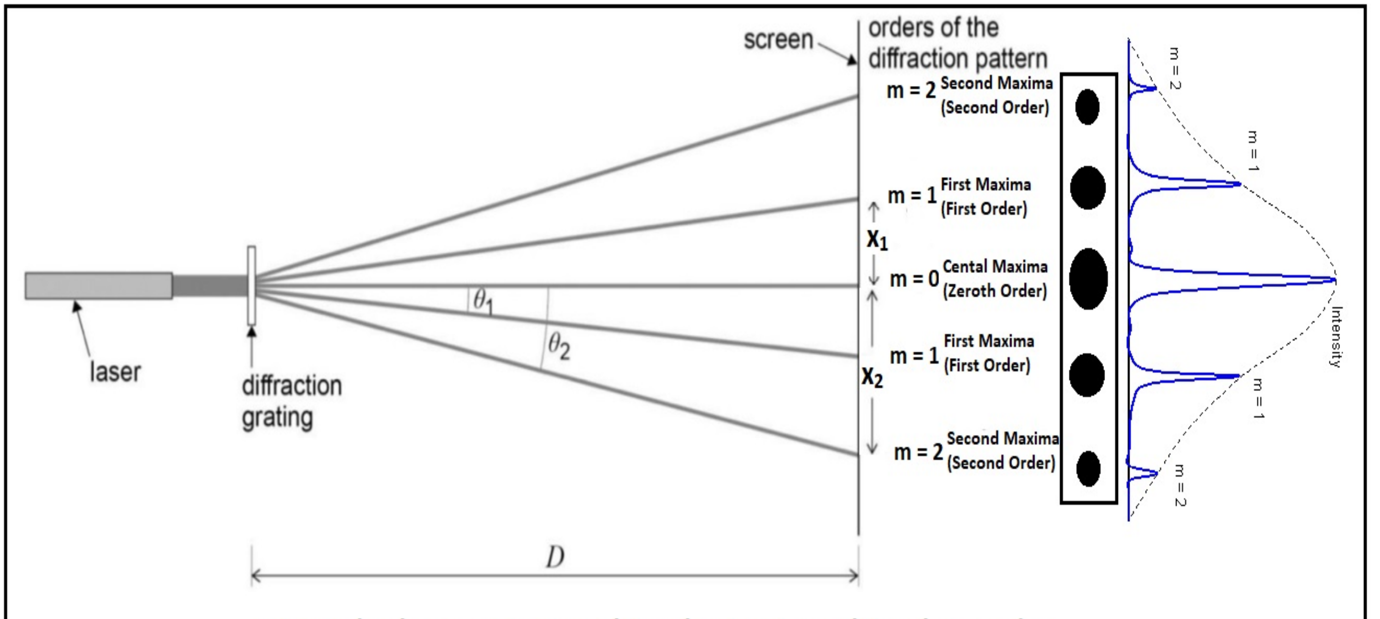
**Result:**

NA =________________

Θ(Acceptance angle)=______________

## Experiment No. 2
## Diffraction of LASER Beam

**Aim:** To determine the unknown wavelength of a LASER Source by the method of Plane Transmission grating.
**Apparatus:** LASER source, grating element, screen, length measuring setup (Say scale, thread), etc.
**Theory:**



Schematic Diagram of LASER Diffraction by Plane Diffraction Grating

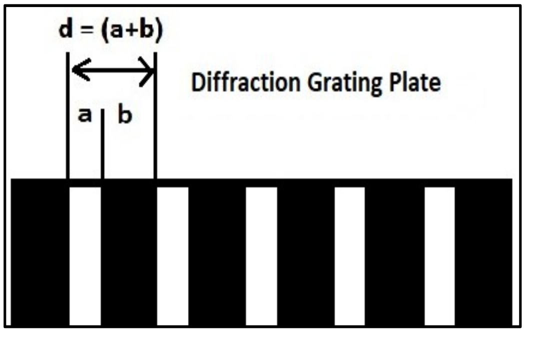
**Schematic Diagram:**

**Formula Required:**

1. Grating Constant: **d = (a+b)** (in cm)
   - $\mathbf{d} = \frac{1}{\textit{Number of lines on grating surface per cm}} = \frac{1}{N}$

     OR
   - $\mathbf{d} = \frac{2.54}{\textit{Number of lines on grating surface per inch}} = \frac{1}{N}$

   Where, a – Width of Transparent Part
   b – Width of Opaque Part




2. Angle of Divergence: $\theta_n$ (in radian)

   $$\theta_n = \tan^{-1}(x_n/D)$$

   - For First Order $\theta_1 = \tan^{-1}(x_1/D)$
   - For Second Order $\theta_2 = \tan^{-1}(x_2/D)$

   Where, $x_n$-distance of point of nth order maxima from central maxima(in cm)

D- Distance between grating and screen (in cm)

3. Wavelength of LASER beam: λ (in nm)

$$\lambda = \frac{d \sin \theta n}{n}$$

where, d – Grating constant
$\theta_n$ – Angle of Divergence
n- Order of spectral line

**Observations and Tabulation**

- Number of lines per cm (or inch), N = ________________________ $cm^{-1}$.
- Grating Constant, d = (a+b) = $\frac{1}{N}$ = ____________________________ cm

| Distance between grating and screen **D** **(in cm)** | Distance of point of nth order maxima from central maxima | | | Angle of Divergence in radian | | Wavelength of LASER beam **λ (in nm)** | |
|---|---|---|---|---|---|---|---|
| | **$x_n$ (in cm)** | | | **$\theta_n$ (in radian)** | | | |
| | To the left of central maxima | To the right of central maxima | Mean distance from central maxima $x_n$ | **$\theta_n$** | **sin $\theta_n$** | **λ** | Mean**λ** |
| **First Order diffraction** | | | | | | | |
| | | | | | | | $\lambda_1$ = ____ |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **Second Order diffraction** | | | | | | | |
| | | | | | | | $\lambda_2$ = ____ |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Calculations:**

Wavelength of given LASER beam is

$$\lambda = \frac{\lambda 1 + \lambda 2}{2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ nm}$$

**Result:**

The wavelength of given LASER beam is found to be ________________ obtained by the method of Plane transmission grating.

## Experiment No. 3
## BEER'S LAW

**Aim:** Verification of Beer's law by photoelectric colorimetric method, Calculate the molar extinction coefficient of $KMno_4$ solution.

**Apparatus:** Photoelectric colorimeter, two matched cell, filters, series of numbered test tubes in rack, graduated pipette, Burette, tissue papers, standard flask, 0.01M $KMnO_4$ solution, distilled $H_2O$.

**Formula:**

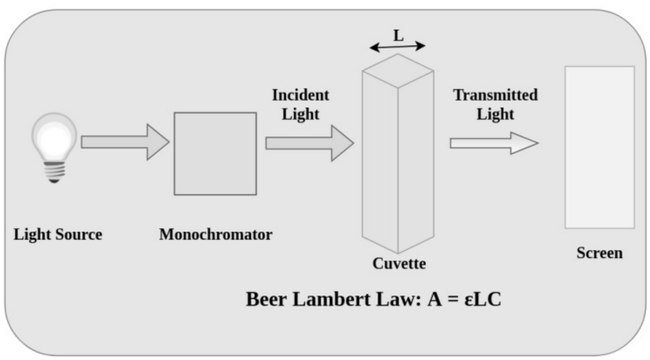
Molar extinction coefficient $\varepsilon = \frac{A}{Cl}$

Where, A-Absorbance or optical density.

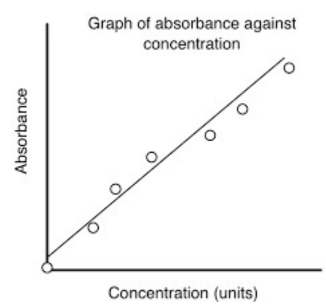
C- Concentration of $KMno_4$ solution.

l- Diameter of matched cells.

**Schematic diagram:**




**Nature of graph:**




**Tabular column:**

**Preparation of Sample**

| Test tube number | Volume of $Kmno_4$ solution | Volume of $H_2O$ | Total Volume |
|---|---|---|---|
| | | | |

Part I: Selection of filter.

| Filter Number | Filtering Wavelength (nm) | Optical density | Transmittance T in % |
|---|---|---|---|
| | | | |

Part II

| Test Tube/ Sample Number | Optical density | Transmittance<br>T in % |
|---|---|---|
| | | |

**Result:**

Beer's law is verified.

## Experiment No. 4
## Spectral Terms of Non-Equivalent Electron Systems

**Aim: Determination of spectral terms for non-equivalent electron systems which are coupled by L-S coupling scheme and show splitting of energy levels with the diagram for following electronic configuration**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **i)** | **ns-n`s** | **ii)** | **ns-np or ns-n`p** | **iii)** | **np-n`p** | **iv)** | **np-nd or np-n`d** |

**Important formulae:**

**For L-S Coupling**

The possible values of S: S= $|s_1\text{-}s_2|$ to $|s_1+s_2|$ **Multiplicity: (2S+1)**

The possible values of L: L= $|l_1\text{-}l_2|$ to $|l_1+l_2|$ States: S, P, D, F, G…… For L=0, 1, 2, 3, 4, 5…..

The possible values of J: J= |L-S| to |L+S| **Spectral Term: $^{(2S+1)}L_J$**

The parity of electronic configuration: **Parity = $\sum_i l_i$**

<u>Term Shifts due to different Interaction Energy</u>

$\Delta T_1 = \frac{a_1}{2}(S^{*2} - s_1^{*2} - s_2^{*2}) = \frac{a_1}{2}[S(S+1) - s_1(s_1+1) - s_2(s_2+1)]$

$\Delta T_2 = \frac{a_2}{2}(L^{*2} - l_1^{*2} - l_2^{*2}) = \frac{a_2}{2}[L(L+1) - l_1(l_1+1) - l_2(l_2+1)]$

$\Delta T_3 + \Delta T_4 = \frac{A}{2}(J^{*2} - L^{*2} - S^{*2}) = \frac{A}{2}[J(J+1) - L(L+1) - S(S+1)]$

**<u>Question I</u>: Determine the spectral terms of ns-n`s electronic configuration which are coupled by LS Coupling scheme and also represent schematically the spectral terms.**

**<u>Question II</u>: Determine the spectral terms of s-p electronic configuration, a non equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

**<u>Question III</u>: Determine the spectral terms of p-p electronic configuration, a non equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

**<u>Question IV</u>: Determine the spectral terms of pd electronic configuration for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

## Experiment No. 5
## Spectral Terms of Equivalent Electron Systems

**Aim: Determination of spectral terms for equivalent electron systems in L-S coupling and show splitting of energy levels with diagram for following electronic configuration**

**i) $ns^2$ ii) $np^2$ iii) $nd^2$ iv) $nf^2$**

**Formulae and Term symbols:**
For two valence equivalent electron system, $n_1 = n_2$ and $l_1 = l_2$ then there arises two cases

**Case (i):** If $m_{l1} = m_{l2}$ then $m_{s1} \neq m_{s2}$ $\rightarrow$ S=0

**Case (ii):** If $m_{l1} \neq m_{l2}$ then $m_{s1} = m_{s2}$ $\rightarrow$ S=1

The possible values of $m_l$: $m_l = -l, \ldots, -3, -2, -1, 0, +1, +2, +3, \ldots, +l$

The possible values of S: $S = |\sum m_s| = |s_1 - s_2|$ to $|s_1 + s_2|$ **Multiplicity: (2S+1)**

The possible values of L: $L = |\sum m_l| = |l_1 - l_2|$ to $|l_1 + l_2|$ **States:** S, P, D, F,.. For L = 0, 1, 2, 3, 4..

$\mathbf{M_L}$ = (-L),..,-3, -2, -1, 0, +1, +2, +3, .., (+L)

The possible values of J: $J = |L-S|$ to $|L+S|$ **Spectral Term:** $^{(2S+1)}L_J$

The parity of electronic configuration: **Parity =** $\sum_i l_i$

<u>Term Shift due to corresponding Interaction Energy</u>

$\Delta T_1 = \frac{a_1}{2}(S^{*2} - s_1^{*2} - s_2^{*2}) = \frac{a_1}{2}[S(S+1) - s_1(s_1+1) - s_2(s_2+1)]$

$\Delta T_2 = \frac{a_2}{2}(L^{*2} - l_1^{*2} - l_2^{*2}) = \frac{a_2}{2}[L(L+1) - l_1(l_1+1) - l_2(l_2+1)]$

$\Delta T_3 + \Delta T_4 = \frac{A}{2}(J^{*2} - L^{*2} - S^{*2}) = \frac{A}{2}[J(J+1) - L(L+1) - S(S+1)]$

**<u>Question I</u>: Determine the spectral terms of $ns^2$ electronic configuration, an equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

**<u>Question II</u>: Determine the spectral terms of $np^2$ electronic configuration, an equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

**<u>Question III</u>: Determine the spectral terms of $nd^2$ electronic configuration, an equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

**<u>Question IV</u>: Determine the spectral terms of $nf^2$ electronic configuration, an equivalent electron system for LS Coupling and also represent schematically the interaction energy between two valence electrons.**

## Experiment No. 1

## Heat Capacity

**Aim:** To determine the specific heat of a given solid sample.

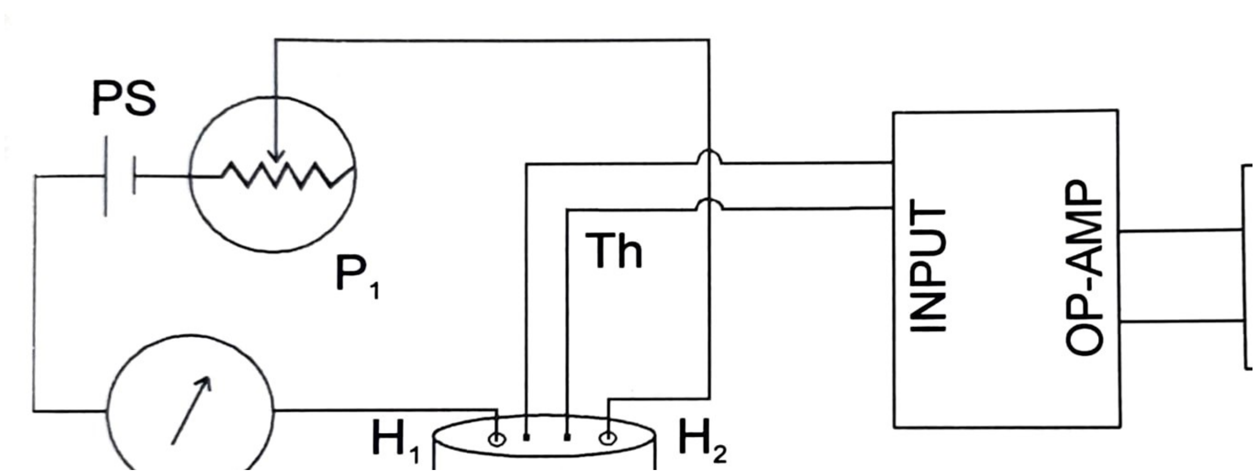
**Apparatus:** Heat Capacity Kit [Electronic circuit housed in a cabinet: Amplifier with Digital display assembly and power supply(for calorimeter heater) in series with Ammeter and Potentiometer with provision for connecting calorimeter heater leads], Silver Calorimeter with Teflon flask, Thermocouple, Patch Cords, Stop watch, Standard Sample (Silver), Test Samples (Aluminum, Brass, Copper).

**Formula Required:**

$$I^2Rt = (W+mS)(T_2-T_1)$$

where,
**I** – Current
**R** – Calorimeter heat Resistance, R= V/I
**t** – Time taken by the sample to increase its temperature by $T_2$ to $T_1$
**W** – Water equivalent of calorimeter
**m** – Mass of the sample
**S**- Specific heat
**$T_1$** – Initial temperature
**$T_2$** – Final temperature

**Diagram:**




**PS-** Power Supply
**$P_1$**-Potentiometer
**A**- Ammeter
**C**-Silver Calorimeter
**Th**- Thermocouple

**Observations and Calculations:**

**Type of Thermocouple Used: ________________**

- **Determination of Water Equivalent of Calorimeter(W):**

  Standard Sample used: ________________

  Specific heat of the standard sample: **S = _________ J $kg^{-1}$. $K^{-1}$**

  Mass of the Standard Sample: **m = ____________ kg**

  Current, **I = __________ A**

  Voltage, **V = ____________ volt**

  Temperatures, $T_2 > T_1$

  Initial temperature $T_1$= ______°C = _______K

  Final temperature $T_2$= ______°C = _______K

  Time taken by the sample to increase its temperature by $T_2$ to $T_1$, **t = _____seconds**

  **Water Equivalent of Silver Calorimeter, W =** $\left(\frac{I^2Rt}{T_2-T_1}\right) - mS$ = ___________________

- **Determination of heat capacity of given samples**

1. **Sample 1**

   Sample used: __________

   Mass of the sample: **m = __________ kg**

   Current, **I = __________ A**

   Voltage, **V = ____________ volt**

   Temperatures, $T_2 > T_1$

   Initial temperature $T_1$= ______°C = _______K

   Final temperature $T_2$= ______°C = _______K

   Time taken by the sample to increase its temperature by $T_2$ to $T_1$, **t = _____seconds**

   **Specific heat of the sample,**

   $$S = \frac{I^2Rt}{m(T_2-T_1)} - \frac{W}{m} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \text{ in J kg}^{-1}\text{K}^{-1}$$

2. **Sample 2**

   Sample used: __________

   Mass of the sample: **m = __________ kg**

   Current, **I = __________ A**

   Voltage, **V = ____________ volt**

   Temperatures, $T_2 > T_1$

   Initial temperature $T_1$= ______°C = _______K

   Final temperature $T_2$= ______°C = _______K

   Time taken by the sample to increase its temperature by $T_2$ to $T_1$, **t = _____seconds**

   **Specific heat of the sample,**

   $$S = \frac{I^2Rt}{m(T_2-T_1)} - \frac{W}{m} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \text{ in J kg}^{-1}\text{K}^{-1}$$

**Procedure:**

1. Measure the masses of Samples (standard sample as well as test samples).
2. Insert the thermocouple junction into the hole of the specimen kept tightly fixed in to the silver calorimeter (Silver calorimeter is attached to the lid of the Teflon flask).Connect thermocouple to the main unit.
3. Connect the calorimeter heater leads to the terminals provided on the front panel of the kit (heater).
4. Suppose that we have to measure the heat capacity of the material at temperature T°C (say 27.5°C) choose temperature $T_1$ as (T-2.5°C) (say, 25°C) and $T_2$ as (T+2.5°C) (say, 30°C).
5. Adjust the heater current control potentiometer $P_1$ so that a current I of 250-300mA passes through the heater as can be read on the current meter. Due to the current flow in the calorimeter heater, the temperature of the specimen increases and as a result the thermo-emf of the thermocouple increases and hence the display reading. When the display reading reaches $T_1$, start the stop watch and note the time t for the temperature to build to $T_2$.
6. Using the relation $I^2Rt = (W + mS)(T_2 - T_1)$
   Determine W employing a standard (Silver) specimen.
7. On repeating the step 2 to 5, the specific heat of the test sample at temperature T can be determined using the value of W calculated above by determining the time required to heat the specimen from $T_1$ to $T_2$ when the same current I pass through the calorimeter heater.

**Precautions:** While switching the stop watch and switching off the stop watch to determine the time required to heat the sample from temperature $T_1$ to $T_2$ $^0$C, it is desirable to see that the condition are identical, when the panel re adding is just displaced $T_1$ start the stop watch and stop the stop watch the display is just $T_2$.

**Result:**

Specific Heat of Sample 1(_______________): _____________________
Specific Heat of Sample 2(_______________):_____________________

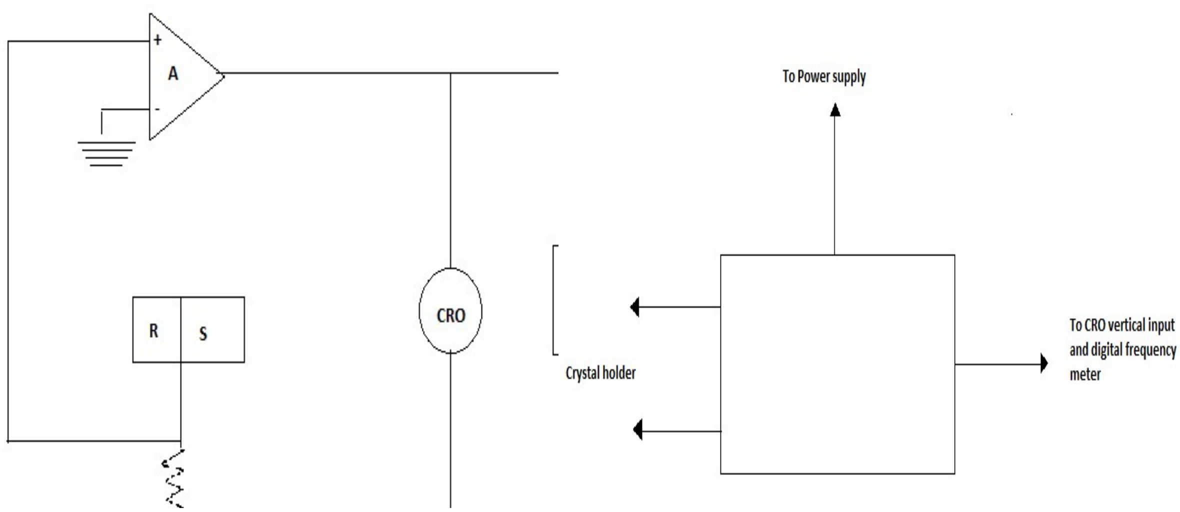
## Experiment No. 2

## YOUNG'S MODULUS

**Aim:** To find the young's modulus of a given sample.
**Apparatus:** Young's Modulus kit, CRO, Crystal holder, Quartz Crystal Sample.
**Formula required:**

1. **Frequency** of the specimen, $f_s = f_c + \frac{m_q}{m_s}(f_c - f_q)$ in kHz
2. **Ultrasonic velocity** in specimen $v = 2f_sL$ in $ms^{-1}$
3. **Young's Modulus** $\gamma = 4f_sL^2\rho$ in $Nm^{-2}$ (or)
4. **Compressibility** $\beta_{ad} = \frac{1}{\rho v^2}$

**Diagram:**




**Observations:**
Sample given: ______________
Mass of Quartz rod: $m_q$=0.9gm
Mass of specimen: $m_s$=1.2gm
Length of the specimen **L**=25.9mm
Density $\rho$=____________$Kgm^{-3}$
Natural frequency of quartz rod: $f_q$=______________ kHz
Natural frequency of composite system: $f_c$=______________kHz

**Procedure:**

1. Measure the masses of the quartz rod and the specimen.Measure the length of the specimen (L) using a micrometre. Calculate density of the specimen.
2. Connect the longitudinal crystal holder with the main circuit using cords supplied with the instrument.
3. Connect the CRO to the main unit using co-axial cable supplied.
4. Insert the longitudinal quartz rod R in the crystal holder such that the holder pins are approximately at the centre of the plated electrode face of the crystal.
5. Vary $R_f$ (TTP) and observe the system oscillating (as indicated by the CRO pattern) above a particular value of $R_f$. measure resonant frequency of the quartz rod ($f_q$).
6. Cement the quartz rod to specimen, in the form of rectangular rod of identical cross-section ,using cementing glue provided.
7. Calculate ultrasonic velocity in the sample and calculate compressibility.

**Result:**

**Natural frequency of specimen $f_s$=__________KHz**
**Ultrasonic wavelength in specimen V=_________$ms^{-1}$**
**Compressibility $\beta_{ad}$=___________$Nm^{-2}$**
**Young's modulus Y=__________$Nm^{-2}$**

## Experiment No. 3

## Determination of Energy Gap using Diode

**Aim:** To determine the energy gap using reserve saturation current in a p-n junction diode.

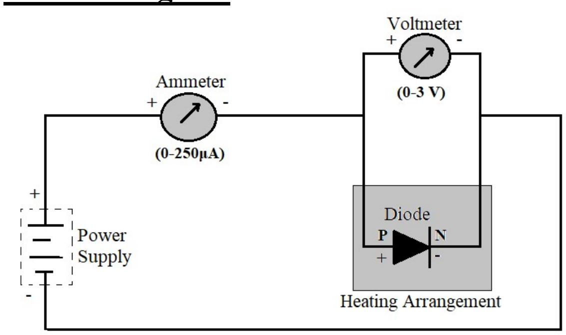
**Apparatus:** Power supply, Ammeter (0-250µA), Voltmeter (0-3V), Diode, Heating arrangement, thermometer and connecting wires.

**Formula:**

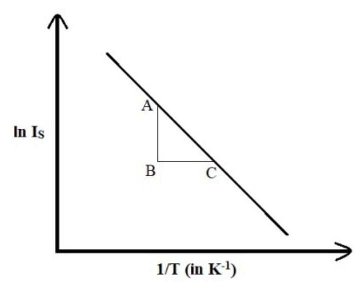
Energy gap $E_g$ $E_g = 2k_B x Slope$ (in eV)

Where, Boltzmann's Constant $k_B = 8.6173x10^{-5}$ ev/k

**Circuit Diagram:**




**Nature of Graph:**




**Observation:**

Given Diode is IN4007

Room temperature= _______ $^0$C

Applied Voltage= ______ volt

Boltzmann Constant, $k_B = 8.854x10^{-5}$ eV

**Tabulation:**

| Sl. No. | Reverse Saturation Current $I_S$ (in µA) | ln $I_S$ | Temperature (in $^0$C) | Temperature T (in K) | Temperature 1/T (in $K^{-1}$) |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Calculation:**

**Procedure:**

- Connect all the components according to circuit diagram.
- Place the thermometer in the heating setup and note down the room temperature.

- Adjust the voltage.
- Start the heating process till the temperature reaches upto $85^0$C.
- Note down the Current across the diode as the temperature decreases for every $5^0$C.
- Plot the graph of ln $I_S$ versus 1/T.
- Using the slope from the graph calculate the energy gap using the formula.

**Result:** The energy gap of given semiconductor (diode) $\mathbf{E_g}$ **= ____________eV**

## Experiment No. 4

## QUINCKE'S METHOD

**Aim:** To Determine the susceptibility using due to the water in the solution of Paramagnetic Salt.

**Apparatus:** Quincke's tube with fitted stand, electron magnetic with power supply , Gauss meter , travelling microscope , Physical balance, experimental salt etc.

**Formula:** Susceptibility of a solution

$\chi=2\rho gh/H^2$ $\rho=\rho_{water} X\ w_2-w_1/w_3-w_1$

Where, g= Acceleration due to gravity

h= Rise in height of the solution

H=applied field

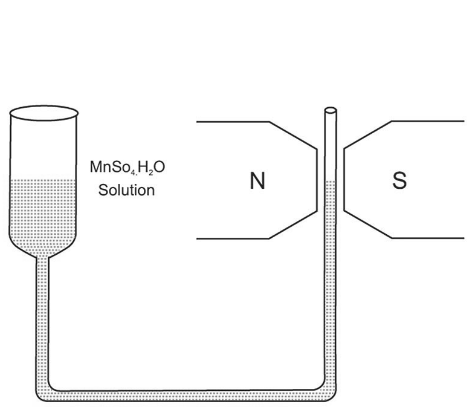
$\rho$= Density of the material.

$w_1$= weight of empty bottle

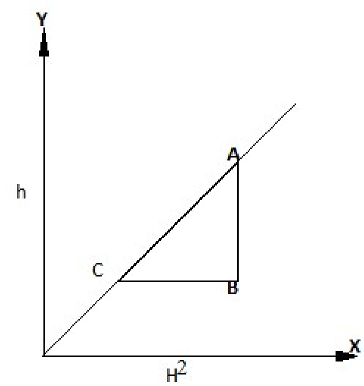
$w_2$=weight of empty sample

$w_3$=weight of empty water

**Diagram:**




**Nature of graph:**




**Observation:**

1) Density of given $FeCl_3$ solution $\rho$ =1.43kgm$^{-3}$

2) Original height of the solution $h_0$=3.4cm

3) Least count of microscope (Travelling) l=0.01mm and

$T_R$=MSR+(CVD+LC)

**Tabular Column-I**

| Sl.No | Current | Magnetic field H(kg) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

**Tabular Column-II**

| Sl.No | Current | Magnetic field H(kg) | $H^2$ ($kG^2$) | Height of the solution in mm $T_R$=MSR+(CVD+LC) | Rise into height of the solution $h=h_0\sim h^I$ |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Procedure:**

1. Test and ensure that each unit (electromagnet and power supply) is functioning properly.
2. Measure the density ʆ of the specimen(liquid or solution) by specific gravity bottle if the mass empty bottle is $W_1$, filledwith specimen $W_2$ and filled with water $W_3$,then ʆ=ʆ$_{water}$ X $w_2$-$w_1$/$w_3$-$w_1$.
3. Scrupulous cleaning of the tube is essential.Thoroughly clean the quincke's tube,rinse it well with distilled water and dry it. Do not use the tube for longer than one laboratory period without pre cleaning it.
4. Keep the quince's tube between the pole pieces of the magnet.The length of the horizontal connecting limb should be sufficient to keep the wide limb out of the magnetic field.
5. Fill the liquid in the tube and set the meniscuscentrallywithin the pole pieces. Focus the microscope on the meniscus and take readings.
6. Apply the magnetic field H and note its value from the calibration, which is done earlier as an auxiliaryexperiment. No: Wheatear the meniscus rises up or descends down. It rises up for paramagnetic liquids and solutions while descends down for diamagnetic. Readjust the microscope on the meniscus and take readings. The differences of these two readings gives h for the field H. The magnetic field between poles of the magnet does not drop to zero even when
7. the current is switched OFF. There is a residual magnetic field R which requires a correction.
8. Measure the displacement h as a function of applied field H by changing the magnet current in small steps. Plot a graph of h as a function of $H^2$.

**Result:**

Susceptibility of a solution $\chi$= ________________

## Experiment No. 1

## Dielectric constant of solids

**Aim:** determine dielectric constant of different constant of solids.

**Apparatus:** Dielectric constant kit (includes inductor, standard capacitor, oscillator, power supply), metal plates, solid samples (glass, wood, Bakelite, $BaTiO_3$ crystal), CRO.

**Formula:** **1)** $C_{DC} = C_{SC}V_{SC}/V_{DC}$

Where $C_{DC}$-capacitance of the dielectric cell containing the sample

$C_{SC}$ – capacitance of standard capacitor

$V_{DC}$ –voltage across dielectric cell

$V_{SC}$ –Voltage across standard capacitor

**2)** $C_0=r^2/36d$_______________nf

Where, $C_0$ –Capacitance of dielectric cell without sample

r – radius of electroplates

d- Thickness of the sample.

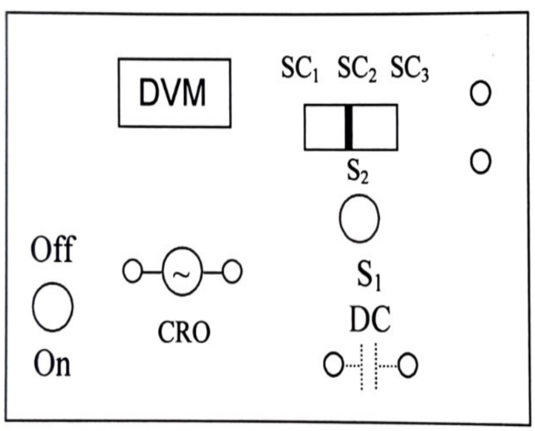
**3)** $\varepsilon_r= C_{DC} / C_0$

where $\varepsilon_r$ - Dielectric constant of given solid samples

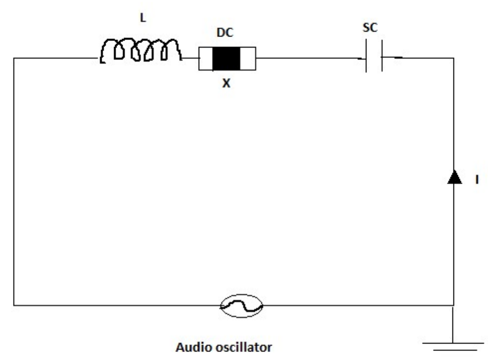
**Diagram:**

**Front panel description**

1. Digital voltmeter (DVM), which measures the voltage across the dielectric cell(DC) or standard capacitor (SC).
2. Switch $S_1$to select dielectric cell or standard capacitor.
3. Switch $S_2$ to select one of the standard capacitors $SC_1$, $SC_2$, and $SC_3$.




**Circuit Diagram**




**Calculation:**

Sample: _____________

$C_{DC}$ =

$C_{SC}$ =

$V_{DC}$ =

$V_{SC}$ =

**Procedure and Precautions in handling the experimental setup:**

1. Connect CRO to the terminals provided on the front panel of main unit. If no sinusoidal waveform appears on CRO then adjust “CAL” such that waveform appear.

2. Connect the dielectric cell assembly to the main unit and insert the sample in between the SS plates.
3. Switch ON the unit.
4. Choose the standard capacitor(with the help of switch $S_2$)$SC_1$ for materials having low dielectric constants (like Bakelite, glass, plywood samples)or $SC_2$ for material having high dielectric constant(PZT sample)
5. Throw $S_1$ towards DC to measure the voltage across dielectric cell, say $V_{DC}$ and towards SCto measure voltage across standard capacitor, say $V_{SC}$. Calculate the capacitance C using relation

$$C_{DC}=V_{SC}/V_{DC} \times C_{SC}$$

**Result:**

Dielectric Constant of __________ is ______________

## Experiment No. 2

## SOLAR CELL CHARACTERISTICS

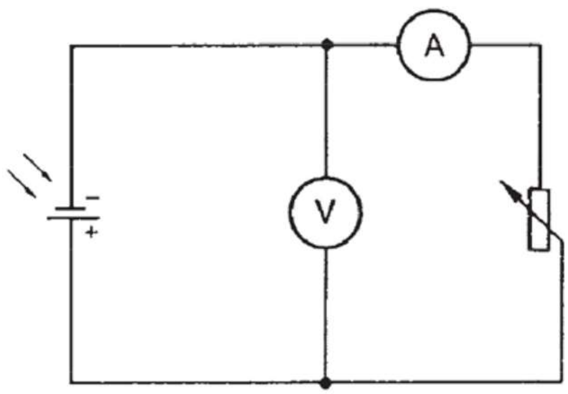
**Aim:** To Study the Characteristics of solar cell by finding open circuit voltage and short circuit current and also find the fill factor of the cell.

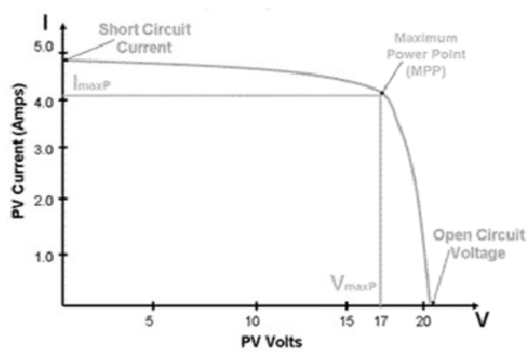
**Apparatus:** 40w bulb, solar cell, Voltmeter, mill ammeter, resistance box and connecting wires.

**Formula:**

1) Ideal Power of the cell= $V_0$ x $I_s$=________mW.
   Where, $V_0$-Open circuit voltage
   $I_s$- Short circuit current
2) Use full power of the Cell = $V_m$ x $I_m$=_______mW
   Where, $V_m$, $I_m$ are the voltage an d current for the area of largest rectangle of I-V curve.
3) Fill Factor = Use full power/Ideal power
   = $V_m$ x $I_m$/$V_0$ x $I_s$

**Circuit Diagram:** **Nature of graph:**




**Observation:**

1) Distance between lamp and cell,d=_______m
2) Open circuit voltage , $V_0$(when $R_L=\infty$) $V_0$ = ______V
3) Short circuit , $I_S$ (when $R_L$=0), $I_S$=_________mA

**Tabulation:**

| Resistance $R_L$ (Ω) | Voltage V(Volts) | Current I (mA) | Power P=VI (mW) |
|---|---|---|---|
| | | | |

**Result:**

**Fill factor of given solar cell is ________________**

## Experiment No. 3

## CURIE-TEMPERATURE DETERMINATION IN FERROELECTRIC MATERIAL

**Aim:** To determine the transition temperature of ferroelectric material ($BaTio_3$).
**Apparatus:** Curie- temperature kit (Consists of inductor, standard capacitor, oscillator, power supply), Dielectric cell, Hot air oven, CRO, Temperature sensor, $BaTiO_3$ sample.
**Formula:**
$C_{DC}=C_{SC}\,V_{SC}/V_{DC}$
Where, $C_{DC}$- Capacitance corresponding to Dielectric cell. $V_{DC}$ – Voltage across dielectric cell.

$C_{SC}$ - Capacitance corresponding to standard capacitance. $V_{SC}$ – Voltage across standard capacitance.

1) $C_0=r^2/36d$ nf
   Where, $C_0$- Capacitance of dielectric cell in air medium.
   r- Radius of electroplates. d- Thickness of Dielectric medium.
2) $\varepsilon_r=C_{DC}/C_0$, Where, $\varepsilon_r$- Dielectric constant of a crystal.

**Observations:**
Inductance L=25mH

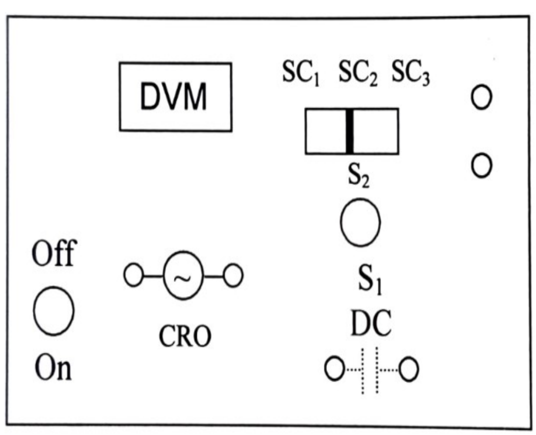
Radius of the electroplates, r=12.5mm

Standard Capacitance , $SC_1$=11nf , $SC_2$=20nf

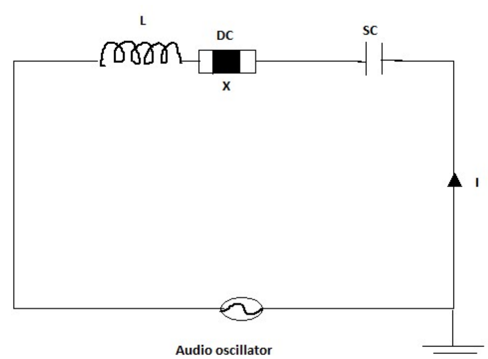
Thickness of the sample ,d=1.8mm

$C_0=r^2/36d$ =0.002411nf

**Diagram:**
**Front panel description**
1. Digital voltmeter (DVM), which measures the voltage across the dielectric cell(DC) or standard capacitor (SC).
2. Switch $S_1$ to select dielectric cell or standard capacitor.
3. Switch $S_2$ to select one of the standard capacitors $SC_1$, $SC_2$, and $SC_3$.




**Circuit Diagram**




**Tabular Column:**

| Temperature ($^0$C) | $C_{SC}$ (in nF | $V_{SC}$ (V) | $V_{DC}$ (V) | $C_{DC}$ (nF) | $\varepsilon_r$ |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**Procedure and Precautions in handling the experimental setup:**

1. Connect CRO to the terminals provided on the front panel. If no sinusoidal waveform appears on C.R.O then follow calibration procedure first.
2. Assemble the dielectric capacitor as shown in figure and connect it to the main unit (for convenience we had send the assembled Dielectric cell).
3. Connect hot air oven to the mains.
4. Place the dielectric cell DC in hot air oven and place the lid on the top. Insert the thermocouple to the hole provided on top Teflon disc of DC via hole provided on the insulating disc. Make sure that thermocouple touches the top metal disc.
5. Switch ON the unit.
6. Select $SC_1$ among standard capacitors.
7. Measure the voltage (using digital voltmeter provided on front panel)across the dielectric cell DC, say $V_{DC}$ by throwing switch $S_1$ towards DC and measure voltage across standard capacitor SC ,say $V_{SC}$, throwing switch $S_1$ towards SC, while heater is switched off(i.e. at room temperature).
   $V_T=V_{SC}+V_{DC}$
8. Determine the dielectric constant of the crystal using the relation
   $\varepsilon_r=c/c_0=C_{SC}xV_{SC}/V_{DC}xC_0$
9. Switch ON the oven and set the desired temperature(Follow instruction to set the temperature of the oven ).measure voltages $V_{DC}$ at different temperatures at $10^0$C interval in the range RT-$90^0$C.$V_{SC}$ may be calculated as $V_{SC}=V_T-V_{DC}$
10. Measure $V_{DC}$ at $5^0$C interval up to $110^0$C and at intervals of $1^0$C - $2^0$C until you reaches the maximum value of the dielectric constants(or C).Thereafter take few points.
11. Make the observation table.
12. Calculate the dielectric constant (as explained in step 8).
13. Draw a graph of $\varepsilon_r$ vs T. At the transition the dielectric constant sharply rises and falls suddenly after the transition temperature and then decreases slowly beyond the transition temperature.
14. Determine the transition temperature (Curie temperature)from the graph.

**<u>Result</u>:**

The Curie temperature of given sample is ________________

# Experiment No. 4

## Determination of $e/k_B$ using Transistor

**Aim:** To determine the ratio of electronic Charge to Boltzmann's Constant.

**Apparatus:**

**Formula:**

$I_c = I_0 \exp(eV_{EB}/K_BT)$

$e/k_B$= Slope /V

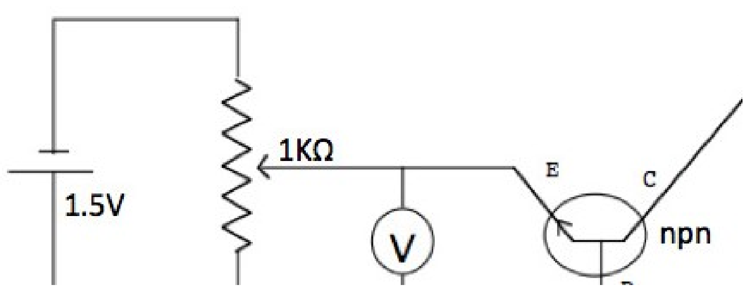
Where, $I_c$= Collect Current

$I_0$= Constant

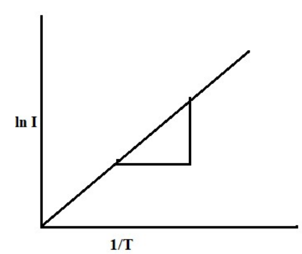
$V_{EB}$=Emitter base-potential difference

$k_B$= Boltzmann's Constant

**Circuit Diagram:**




**Nature of graph:**




**Observation and Tabular Column:**

**Voltage V=_____________**

| Temperature in $^oC$ | Temperature in K | 1/T | $I_C$ | ln ($I_C$) |
|---|---|---|---|---|
| | | | | |

**From slope we get**

**$e/k_B$ =**

**Result:**

The ratio of electronic Charge to Boltzmann's Constant verified.