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M.Sc Physics(Previous)

Paper V : Practical I - General

1. Thermistor – Study of variation of resistance with temperature
2. Photo Cell – Study of characteristics and determination of Planck's constant
3. Determination of elastic constants of glass( $Y$  &  $\sigma$ )
4. Cauchy's constants
5. Wavelength of Laser source light
6. Constant K ladder filter
7. Ultrasonic Interferometer
8. To determine the Dielectric constant of given liquid by the method of mixtures.
9. Variation of Magnetic field with current and distance
10. PT-100 probe determination of temperature coefficient of Resistance of Platinum and melting Point of wax.
11.  $e/m$  of electron by Thomson's method
12. To study the frequency response characteristic of Twin T filter

## Experiment No. 1

### Thermistor

**Aim:** To draw the resistance versus temperature and voltage – current characteristics of a given thermistor.

**Apparatus:** Thermistor, Heating bath, Thermometer, Voltmeter, Ammeter.

**Theory::** Thermistors are semiconductors, which act as temperature sensitive devices and exhibit negative temperature coefficient of resistance. i.e, the resistance of thermistor decreases as temperature is increased. Commercial thermistor consists of sintered mixtures of oxides NiO, Mn<sub>2</sub>O<sub>3</sub> and Cr<sub>2</sub>O<sub>3</sub>. As the temperature increases more charge carriers are liberated which results in increased conductivity. The decrease in resistivity of thermistor follows an exponential curve with temperature. Thermistor finds its applications in thermometry in measurement of microwave frequency power, as a thermal relay (sensors) and in control devices. The resistance of a given thermistor varies with temperature according to the relation  $R = Ae^{B/T}$  Where A and B are constants and T is absolute temperature. The constants A and B are characteristics of thermistor used. Taking logarithms on both sides

$$\log_e R = \log_e A + (B/T)$$

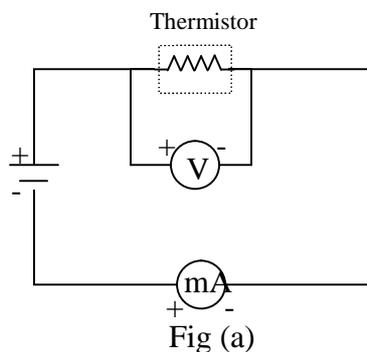
$$2.303 \log_{10} R = 2.303 \log_{10} A + (B/T)$$

$$\log_{10} R = \log_{10} A + 0.4343(B/T)$$

A graph is drawn between  $\log_{10} R$  and  $(1/T)$  It is a straight line graph as shown in figure2. The slope XY/YZ gives the value of 0.4343 B. Hence B can be calculated. The constant A can be calculated from the formula  $\log_{10} A = \log_{10} R - 0.4343(B/T)$ .

By finding R at a known temperature T and substituting the value of B in the above equation A can be found.

#### Circuit Diagram:



**Procedure:**

Make the connections as per circuit diagram. Insert thermometer in the socket provided on the front panel. Keep D.C voltage selector to 5V. Switch ON the D.C supply as well as heater. Note down the ammeter reading for equal and sufficient intervals of time.

**Graph:**

Plot the graph between resistance of thermistor and temperature.

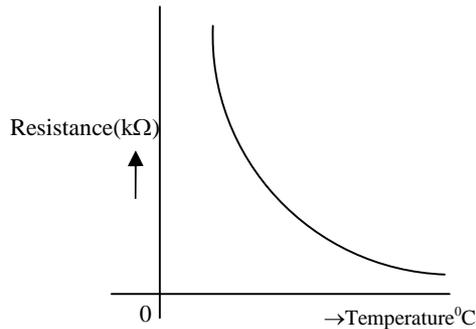


Fig. 1

A graph is drawn between  $\log_{10}R$  and  $(1/T)$ . It is a straight line graph as shown in figure 2. From the graph the values of A and B are calculated. The voltage-current characteristics can be studied by drawing a graph between varying voltage and current noted. The graph is as shown in fig. 3, which is a non-linear indicating that thermistor is a non-Ohmic device.

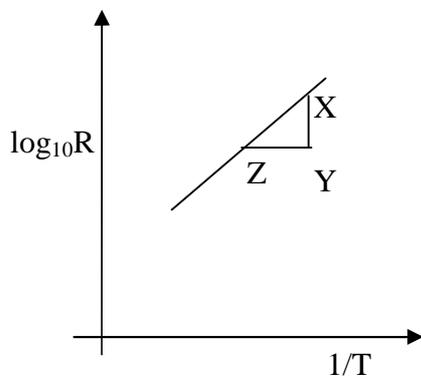


Fig. 2

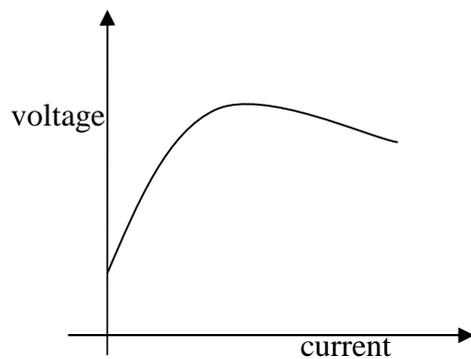


Fig. 3

**Observation Table:**

S.no	Temperature $^{\circ}C$	Voltage(V)	Current (mA)	Resistance (kΩ) $R=V/I$

**Precautions:**

1. The connections should be done carefully.
2. The resistance should be noted carefully.
3. Do not over heat the thermistor.
4. Handle the thermometer carefully.

**Result:**

Resistance versus Temperature characteristics of a given thermistor has been studied.

## Experiment No. 2

### PHOTO CELL

**Aim:** To study the characteristics of Photo cell and to determine the value of Planck's constant.

**Apparatus:** Photo Cell, Light Source, Power supply, Colour filters, Connecting wires, Voltmeter and Micro ammeter.

**Photocell:**

It consists of an electrode made up of Photoelectric metal and another electrode sealed in an evacuated glass tube.

**Principle:**

When light is incident on alkali metals like Sodium, Potassium, Lithium, Cesium etc, electrons are emitted. The emission of electrons from the metal surfaces under the action of radiation is known as Photoelectric effect. This phenomenon was first observed by Hertz in 1887. The electrons so emitted are called photoelectrons. If such metal surface is given a negative potential then electrons fly from the cathode and reach anode thereby constituting a current called as Photocurrent.

Einstein explained photoelectric effect in 1905 on the basis of quantum theory of light. Einstein equation for photoelectric effect is given by

$$h\nu = (1/2)mv^2 + W_0$$

Where  $h$  = Planck's constant

$\nu$  = Frequency of incident radiation

$m$  = mass of electron

$v$  = velocity of the electron

$W_0$  = Work function

**Work function:** The amount of work done in liberating or extracting electrons from the metal surface is known as work function  $W_0$ .

**Stopping Potential:** For a particular frequency of radiation, the current stops at a particular negative potential. The negative potential that stops the current is known as stopping potential (or) the negative potential of electrode that can stop the most energetic photoelectrons is called as stopping potential.

When photo metal is at stopping potential the photocurrent becomes zero.

**Threshold Frequency:** For a particular metal if frequency of radiation is gradually decreased, the photoelectric effect ceases at a particular frequency called threshold frequency. It means that electrons are liberated from the metal surface with zero velocity.

**Procedure:****(a) To study the characteristics of photocell**

1. The circuit diagram to study characteristics of photocell is shown in fig1. The potential is made positive with respect to another electrode. The potential between cathode and anode are applied by means of a potential divider and the applied potential is measured. A micro ammeter is used to measure the current.
2. The light from the source is passed through the optical filter and made to fall on the photometal. The filter allows a light of known frequency. The photo current is measured for a given potential difference.
3. The photocell is placed at various distances (say 15.,20,25..cms) and the potential difference is varied keeping intensity and frequency constant, the variation in current is noted. A set of observations of current and voltage are noted. As voltage is increases, current increases linearly and reaches saturation.
4. The variation of the photocurrent (I) with potential (V) is shown by plotting a graph taking voltage on X-axis and current I on Y-axis for various distances as shown in fig2.

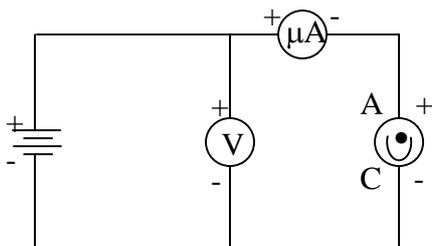


Fig 1

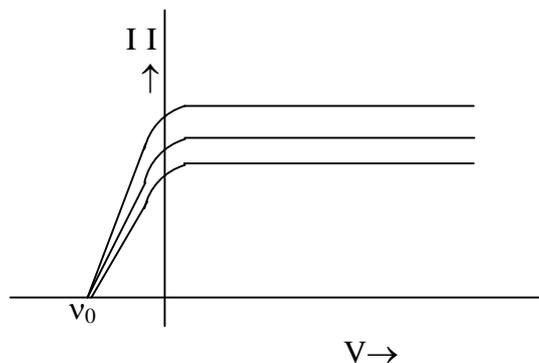


Fig 2

**(b) To determine and planck's constant, work function and cut off frequency.**

- i. The circuit diagram to determine Planck's constant, work function and cut off frequency is as shown figure(3) The white light from a strong source is passed through the optical filter. The filter allows light of known frequency. The potential difference is adjusted so that the current becomes zero. The minimum value of the potential difference is noted.
- ii. The experiment is repeated with number of optical filters and voltages are found. A graph is plotted between the known frequency on X-axis and the corresponding stopping potentials on Y-axis as shown in fig 4. A straight line is obtained. We get the following information from the graph.

Threshold frequency:

The intersection of the extrapolated straight line with X-axis gives threshold frequency  $\nu_0$ . We know that work function  $W_0 = h\nu_0$  where  $\nu_0 =$  threshold frequency. Now using Einstein's equation we get

$$h\nu = \frac{1}{2}mv^2 + W_0$$

$$\text{At stopping potential } \frac{1}{2}mv^2 = eV_s$$

Where  $V_s =$  Stopping potential

Therefore  $h\nu = eV_s + W_0$

$$eV_s = h\nu - W_0$$

$$eV_s = h(\nu - \nu_0)$$

$$h = eV_s / (\nu - \nu_0) \quad \text{here } e = 1.6 \times 10^{-19} \text{ coulombs}$$

- iii. The extension of the straight line onto the negative Y-axis gives the value of  $(W_0/e)$ . From the slope of the straight-line we get the value of  $(h/e)$ . From these values of  $h$  can be calculated. Hence the values of the  $h$  and  $W_0$  are found.

**Circuit diagrams**

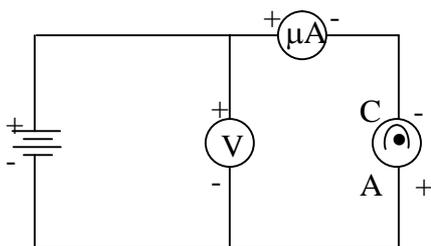


Fig 3

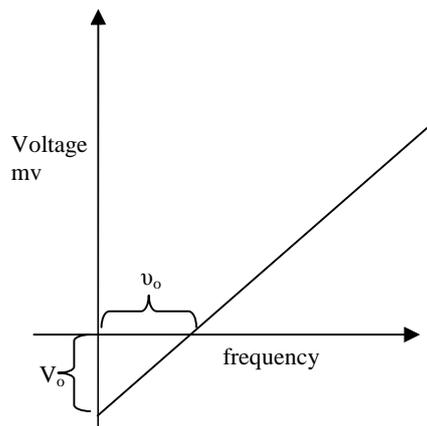


Fig 4

**Observations:**

**(a) To study the characteristics of photocell**

Photocell at a distance of 15 cms.		Photocell at a distance of 20 cms.		Photocell at a distance of 25 cms.	
Voltage(V) volts	Current(I) MA	Voltage(V) volts	Current(I) mA	Voltage(V) volts	Current(I) MA

**(b) To determine and planck's constant, work function and cut off frequency.**

S.No	Filter	Wave length (A°)	Voltage (V)	Frequency(Hz)

**Precautions:** 1) The photo electrode cell should be carefully handled.

2) The connections should be done carefully.

3) The stopping potentials should be noted carefully.

**Result:** Standard value of  $h = \dots\dots\dots$  Joule- sec

Calculated Value of  $h = \dots\dots\dots$  Joule- sec.

Work function of the given metal =  $\dots\dots\dots$  Joule

Experiment No. 3

### ELASTIC CONSTANTS

**Aim:** To determine the young's modulus, Poisson's ratio, Bulk modulus and Rigidity modulus of the given transparent plate like glass plate/Perspex.

**Apparatus :** X-Y microscope, H-stand, Transparent plate, double convex lens, knife edges, Weight hanger, Screw gauge, Vernier calipers.

**Formula:**

1. **Young's modulus of the beam,**

$$Y = \frac{12 mgl}{bd^3(m-n)\lambda \left( \frac{1}{K_2} - \frac{1}{K_1} \right)}$$

Where

- l = Distance between knife edge and the load suspended
- b = Mean breadth of glass plate
- d = Mean thickness of glass plate
- $\lambda$  = Wavelength of light used (Sodium)
- g = Acceleration due to gravity
- m = Mass attached to the glass plate

2. **Poisson's ratio:**

$$\sigma = \left[ \frac{\frac{1}{K_2^1} - \frac{1}{K_1^1}}{\frac{1}{K_2} - \frac{1}{K_1}} \right]$$

$K_1 \rightarrow$  Mean value of  $(\rho_m^2 - \rho_n^2)$  in the longitudinal direction for weight "W<sub>1</sub>" gms.

$K_1^1 \rightarrow$  Mean value of  $(\rho_m^2 - \rho_n^2)$  in the transverse direction for weight "W<sub>1</sub>" gms.

$K_2 \rightarrow$  Mean value of  $(\rho_m^2 - \rho_n^2)$  in the longitudinal direction for weight "W<sub>2</sub>" gms.

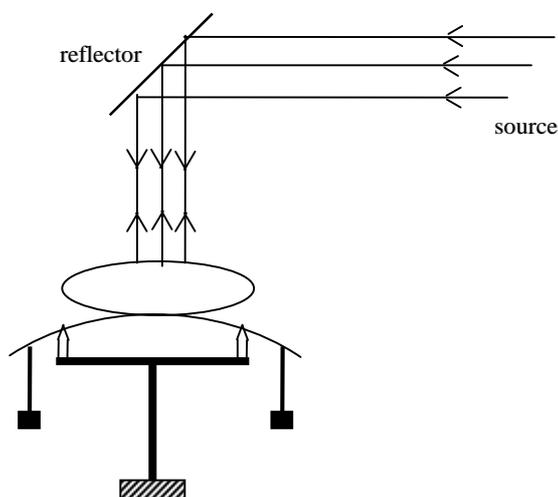
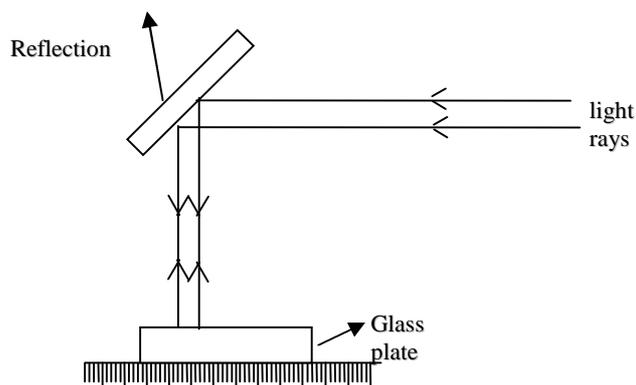
$K_2^1 \rightarrow$  Mean value of  $(\rho_m^2 - \rho_n^2)$  in the transverse direction for weight "W<sub>2</sub>" gms.

### 3. Bulk Modulus

$$\eta = \frac{Y}{2(1+\sigma)} Nm^{-2}$$

### 4. Rigidity Modulus: $K = \frac{Y}{3(1+2\sigma)} Nm^{-2}$

#### Experimental Set up:



#### Procedure:

The experimental glass plate is put over the knife edge such that equal projections are made on either side. Two weight hangers with a load of  $W_1=150\text{gms}$  are attached to the plate near the edges at equal distances to provide uniform bending. With sodium light elliptical fringes are formed using a convex lens.

Now the microscope is focussed at the centre of the ring system. The microscope is moved so that the cross wire passes over 'n' dark rings (say 30). Then the microscope is moved back and readings are noted for (n-5), (n-10), (n-15) etc until the central

fringe is reached. The microscope readings corresponding to 5,10,15,20---n on the other side of the centre are noted. From these values find  $(\rho_m^2 - \rho_n^2)$  for  $m-n = 5$ . The mean values of  $(\rho_m^2 - \rho_n^2)$  is noted  $K_1$ . Repeat the above procedure in transverse direction and note down as  $K_1^1$ .

The experiment is repeated for another load  $W_2$  (say 200gms), and the mean values are noted as  $K_2$  and  $K_2^1$  for longitudinal and transverse directions.

**Observations:**

Table .1

Longitudinal( $K_1^1$ )  $W_1$ gms L.C=...

Number of Fringes	Micro scope Reading		Difference $2\rho$ cm	$\rho$ cm	$\rho^2$	$(\rho_m^2 - \rho_n^2)$
	Left(cm)	Right(cm)				
n+18						
n+15						
'						
'						
'						
n						

Mean

Table .2  $W_1$ gms

Transverse( $K_1^1$ )

Number of Fringes	Micro scope Reading		Difference $2\rho$ cm	$\rho$ cm	$\rho^2 \cdot 10^{-4}$ m <sup>2</sup>	$(\rho_m^2 - \rho_n^2) \cdot 10^{-4}$ m <sup>2</sup>
	Left(cm)	Right(cm)				
N+18						
N+15						
'						
'n						

Mean

Table .3

Transverse( $K_2$ )  $W_2$  gm

Number of Fringes	Micro scope Reading		Difference $2\rho$ cm	$\rho$ cm	$\rho^2 \cdot 10^{-4}$ m <sup>2</sup>	$(\rho_m^2 - \rho_n^2) \cdot 10^{-4}$ m <sup>2</sup>
	Left(cm)	Right(cm)				
n+18						
n+15						
'						
'						
'						
n						

Mean

Table 4:

 $W_2$  gmTransverse( $K_2^{-1}$ )

Number of Fringes	Micro scope Reading		Difference $2\rho$ cm	$\rho$ cm	$\rho^2 10^{-4}$ m <sup>2</sup>	$(\rho_m^2 - \rho_n^2) 10^{-4}$ m <sup>2</sup>
	Left(cm)	Right(cm)				
n+18						
n+15						
'						
'						
n						

Mean

To find the breadth of the glass plate (b) [using Vernier caliper]

Least count =

S.no	M.S.R	V.S.R	V.S.R×L.C	T.R=M.S.R+(VSC XL.C)

Mean

To find the thickness of the glass plate (d) [using screw gauge]

Least count=....

Zero Error=....

Zero Correction=....

S.no	PSR×L.C (a)	HSR(b)	T.R (a+b)	CR= TR+ Zero correction
1				
2				
3				
4				
5				

**Precautions:**

1. The lens and glass plate is to be cleaned without dust before doing the experiment.
2. The readings are taken with out parallax error.
3. Weights should be added without disturbing the setup.
4. The microscope should be moved in one direction only.

**Result:**

The Young's modulus of the given beam =

Poisson's ratio =

Bulk modulus of the given beam =

Rigidly modulus of the given beam =

Experiment No. 4

## CAUCHY'S CONSTANTS

### Aim:

To determine the Cauchy's constants in the Cauchy's relation using spectrometer and prism

### Apparatus:

Spectrometer, Mercury vapour lamp, spirit level, prism, telescope, magnifying lens, and mirror.

### Principle:

The refractive index increases with decrease in wavelength according to the relation

$$\mu = A + \frac{B}{\lambda^2}$$

This relation is known as Cauchy's relation, where  $\mu$  is refractive index of given material for the wavelength  $\lambda$ , A and B are constants of the medium to be determined. If  $\mu_1$  and  $\mu_2$  are refractive indices corresponding to the wavelengths  $\lambda_1$  and  $\lambda_2$  respectively. Then

$$\mu_1 = A + \frac{B}{\lambda_1^2} \quad \text{and} \quad \mu_2 = A + \frac{B}{\lambda_2^2}$$

Solving the two equations  $A = (\mu_1\lambda_1^2 - \mu_2\lambda_2^2) / (\lambda_1^2 - \lambda_2^2) \text{ cm}^2$

$$B = (\mu_2 - \mu_1) \lambda_1^2 \lambda_2^2 / (\lambda_1^2 - \lambda_2^2) \text{ cm}^2$$

Knowing  $\mu_1$  and  $\mu_2$ ,  $\lambda_1$  and  $\lambda_2$  for any of the spectral colors A and B are calculated.

### Procedure:

The preliminary adjustments are done for the spectrometer. To determine the angle of the prism, the prism is mounted on the prism table with refracting edge of the prism perpendicular to the axis of the collimator. The position of the telescope is adjusted until the vertical crosswires coincides with the image of the slit. The reading of the Vernier scales are taken. The telescope is now rotated towards the second polished surface of the surface and the vertical crosswires is made to coincide with the reflected image of the slit. The readings of the Vernier scales are taken, the difference of the readings in Vernier 1 and Vernier 2 is equal to  $2A$ . From this we can calculate the angle of prism (A).

### Determination of refractive index( $\mu$ ):

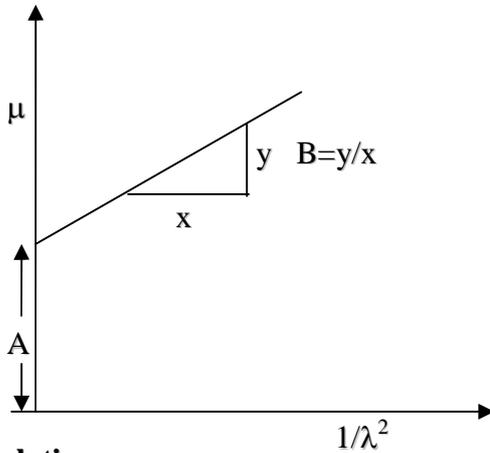
The spectrometer is placed opposite to the source. The width of the slit is adjusted viewing through the telescope. A small mirror strip is attached to the telescope of the spectrometer near over its eyepiece perpendicular to the axis of the telescope. At a distance of about one meter another telescope is arranged with a horizontal scale.

Now the telescope is focussed on the image of the scale seen in the mirror. The prism is adjusted for portion of minimum deviation so that the violet line of the spectrum is brought into the focus of the telescope and made to coincide with the cross wires of the telescope of the spectrometer. Now looking through the telescope, the scale reading that coinciding with the vertical crosswire is noted.

This experiment is repeated by making the other spectral lines coincide with the vertical crosswire and the corresponding scale reading is noted.

**Graph:**

A graph is drawn between  $\mu$  and  $1/\lambda^2$ . Taking  $1/\lambda^2$  values on X-axis and  $\mu$  values on Y-axis. A straight line is obtained. The slope of the straightly line gives the value of "B". The y intercept gives the value of A.



**Calculations:**

$$S_0 = S_1 - \frac{(S_3 - S_1)}{\frac{(\lambda_1 - \lambda_2)(S_3 - S_2)}{(\lambda_2 - \lambda_3)(S_2 - S_1)} - 1}$$

$$C = \frac{(\lambda_1 - \lambda_2)(S_1 - S_0)(S_2 - S_0)}{(S_2 - S_1)}$$

$$\lambda_{ob} = \lambda_1 - \frac{C}{S_1 - S_0}$$

$$\lambda_{cal} = \lambda_0 + \frac{C}{S_1 - S_0}$$

**Observations**

Least count of the spectrometer =  $S/N =$

To find the angle of prism

Ray	Ver.A	Ver.B	2A		Mean 2A	A
			Ver.A	Ver.B		
Reflected from One face						
Reflected from other face						

Spectrum colour	Spectrometer reading		Angle of Min. Deviation		Mean D	$\mu$	Calculated wavelength	Standard wavelength
	Ver.A	Ver.B	Ver.A	Ver.B				
Violet-1 Violet-2								
Blue-1 Blue-2								
Green-1 Green-2								
Yellow-1 Yellow-2								
Orange-1 Orange-2								
Red-1 Red-2								

Colour	$\mu$	$1/\lambda^2$
Violet		
Blue		
Bluish Green		
Green		
Yellow		
Orange		
Red		

**Precautions:**

1. The telescope is adjusted by focussing the object perfectly.
2. The spectrometer is adjusted in such a way that the prism table, collimator, telescope are in same plane.
3. Readings are taken without parallax error.

**Result:**

Cauchy's constants are determined.

*Theoretical values*      *Practical values*

A=

B=

Experiment No. 5

### DETERMINATION OF WAVELENGTH OF LASER

**Aim:** To determine the wavelength of light from He-Ne laser from diffraction pattern.

**Apparatus:** Laser source, grating, scale

**Theory:** He-Ne are mixed in the ratio 10:1 and enclosed in tube. when mixture of gases is subjected to a strong electric field helium atoms are excited to higher states, collide with neon atoms in ground state. The neon atoms are excited to higher energy levels  $Ne_4$  and  $Ne_6$  population inversion takes place. Then stimulated emission of radiation occurs. The light from He-Ne laser is red and monochromatic.

**Formula:**

$$\theta = \tan^{-1}\left(\frac{d}{2D}\right)$$

where  $\theta$  = angle of diffraction

$d$  = distance between centre spot of laser to either side of spot in cm

$D$  = distance between the wall and grating in cm

By this formula we can calculate the angle  $\theta$

when a beam of parallel laser is normally incident on the surface of the plane diffraction angle is related to wavelength by equation.

$$\sin \theta = Nn\lambda$$

where  $n$  = order of the spectrum

$\lambda$  = wavelength

$N$  = number of lines per cm

$\theta$  = angle of diffraction

**Principle:**

Laser beam is a coherent beam of light from a source. When this coherent beam of light is incident normally on a grating, a diffraction pattern of spots is obtained. The number of spots obtained is related to order of spectrum depends on intensity of laser. By calculating the angle  $\theta$ , the wavelength of the laser can be calculated.

**Procedure:**

A laser is used as a source of the laser beam. A grating is placed normal to the direction of incidence of the beam. The beam is projected on a wall, which is at a distance of more than one meter. A diffraction pattern with a bright central spot is obtained. Two more spots are observed on each side of the central spot. Now, the distance between the wall to the grating,  $D$ , is calculated by means of a scale.

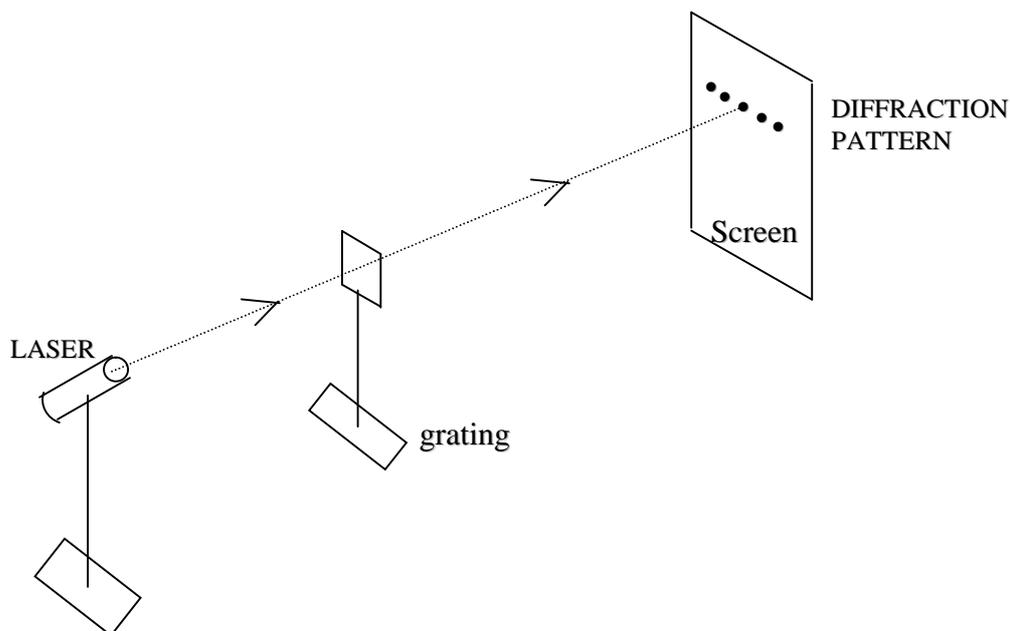
The distance between the central spot to the either side of the spot is also calculated for both 1<sup>st</sup>, 2<sup>nd</sup>, .....n<sup>th</sup> order spots. Thus, the angle  $\theta$  is calculated using the formula,

$$\theta = \tan^{-1}\left(\frac{d}{2D}\right). \text{ Now the wavelength of laser is given by}$$

$$\lambda = \frac{\sin \theta}{Nn}$$

N = number of lines per cm on grating =

Standard wavelength of laser =



### Observations:

Least Count: = S/N =

S.NO	ORDER	D (cm)	LEFT(d/2) (cm)	RIGHT(d/2) (cm)	MEAN(d/2) (cm)	$\theta$

### Calculation:

$$\theta = \text{TAN}^{-1}(d/2D), \quad \theta = \text{angle of diffraction,}$$

'd' = distance between centre spot of laser to either side of spot in cm

D = distance between the wall and grating in cm

$$\lambda = \frac{\sin \theta}{Nn}$$

where n = order of the spectrum, N = number of lines per centimeter in grating.

**Precautions:**

1. The readings are taken when the spherical lines are in normal incidence position.
2. Readings are taken without parallax error.

**Result:**

The standard wavelength of laser is  $6328 \text{ \AA}$

The calculated wavelength for the 1<sup>st</sup> order ( $\lambda_1$ )=      , 2<sup>nd</sup> order ( $\lambda_2$ ) =

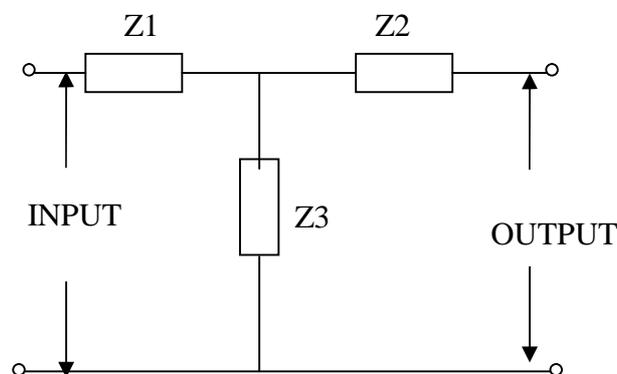
Experiment No. 6

### CONSTANT K – LADDER FILTER:

**Aim:** To construct a constant –K high pass and low pass filter circuits and to study their frequency response characteristics.

**Apparatus:** An audio frequency generator, capacitors, inductances, resistance box, Multimeter and connecting wires etc.,

**Diagrams :**



**Theory:** An ideal filter would pass all frequencies in a given band without reduction in magnitude and totally suppress all other frequencies. Such ideal performance is not possible but can be approached with complex designs, if the need warrants. Filter circuits are widely used and vary in complexity from the relatively simple power-supply filter of an a-c operated radio receiver to complex filter sets used to separate the various voice channels in carrier-frequency telephone circuits. Whenever alternating currents occupying different frequency bands are to be separated filter circuits have an application. Here analysis of filter circuits is carried out on the basis of certain definitions from the general field of electric network theory, under the assumption of symmetrical network sections.

A ladder network can be considered as a chain of symmetrical T-networks one section, which is shown in fig 1. The characteristic impedance of the T network is given by

$$Z_0 = (Z_1^2/4) + Z_1 Z_2.$$

The ratio of input to output voltage is given by  $e^\gamma$ .  $\gamma$  is called propagation constant.

For T networks the propagation constant is related  $Z_1$  and  $Z_2$  by the relation

$$\sinh \frac{\gamma}{2} = \sqrt{\frac{Z_1}{4Z_2}}$$

Ideally it is desired that a filter network transmit or pass a desired frequency band without loss, whereas it should or completely attenuate all undesired frequencies. The propagation constant  $\gamma = \alpha + j\beta$ , being a function of frequency can supply information on the ability of the filter to

perform as desired. If  $\alpha=0$  or  $I_1=I_2$ , then there is no attenuation, only phase shift, in transmitting a signal through the filter, and operation is in a pass band of frequencies. When  $\alpha$  has a positive value, then  $I_2$  is smaller in magnitude than  $I_1$ , attenuation has occurred and operated is in an attenuation or stop band of frequencies.

A pass band was shown to exist with  $X_1$  and  $X_2$  were of opposite reactance types and  $-1 < X_1/4X_2 < 0$ .

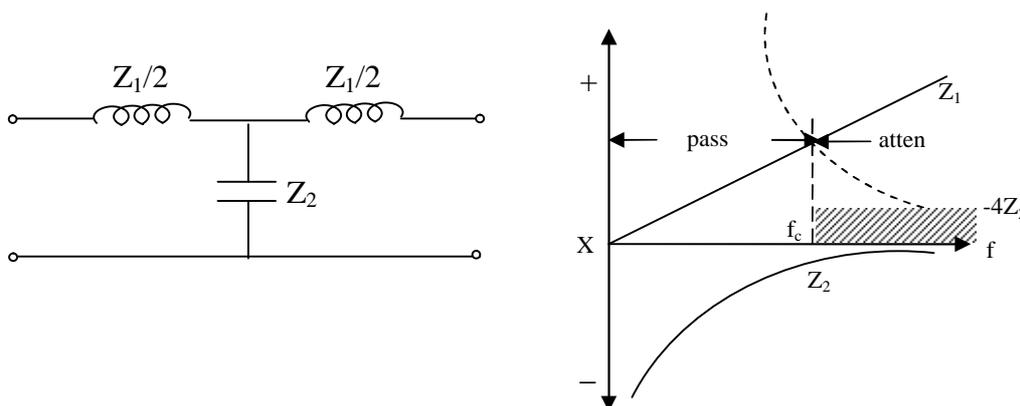
If  $Z_1$  and  $Z_2$  of a reactance network are unlike reactance network are unlike reactance arms, then

$$Z_1 Z_2 = k^2$$

where  $k$  is a constant which is independent of frequency. Networks or filter sections for which this relation holds are called constant- $k$  filters.

As a special case, let  $Z_1 = j\omega L$  and  $Z_2 = -1/j\omega C$ , then the product  $Z_1 Z_2 = L/C = R_k^2$

The terms  $R_k$  is used since  $k$  must be real if  $Z_1$  and  $Z_2$  are of opposite type. A T section so designed would appear would as in fig (a). The reactances of  $Z_1$  and  $4Z_2$  will vary with frequency as sketched in fig (b). The curve representing  $-4Z_2$  may be drawn and compared with the curve for  $Z_1$ . The reactance curves show that a pass band starts at  $f=0$  and continues to some higher frequency  $f_c$ . All frequencies above  $f_c$  lie in a stop, or attenuation band. Thus the network is called a low-pass filter.



The cut-off frequency  $f_c$  may be readily determined, since at that point

$$Z_1 = -4Z_2, j\omega_c L = \frac{4j}{\omega_c C}, f_c = \frac{1}{\pi\sqrt{LC}}$$

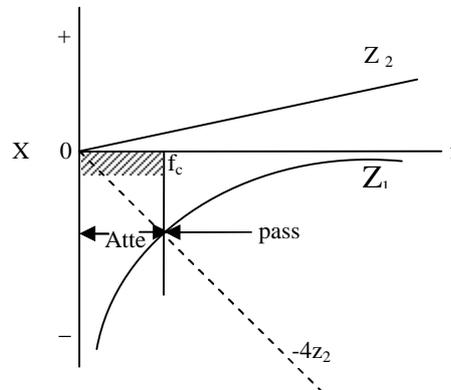
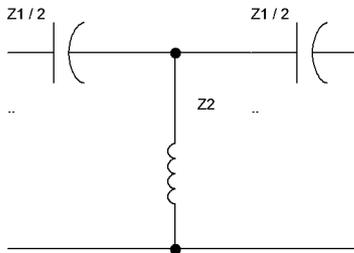
### The constant $-K$ high pass filter:

If the positions of inductance and capacitance are interchanged to make  $Z_1 = -j/\omega C$  and  $Z_2 = j\omega L$ , then  $Z_1 Z_2 = k^2$  and the filter design obtained will be of the constant- $k$  type. The T section will then appear as in (a). The reactances of  $Z_1$  and  $Z_2$  are sketched as functions of frequency in (b), and  $Z_1$  is compared with  $-4Z_2$ , showing a cutoff frequency at the point at which  $Z_1$  equals  $-4Z_2$  with a pass band from that frequency to infinity where  $Z_1=0$ . The network is thus a high-pass filter. All frequencies below  $f_c$  lie in an attenuation, or stop, band.

The cutoff frequency is determined as the frequency at which  $Z_1 = -4Z_2$ , or  $4\omega_c^2 LC = 1$

$$\frac{-j}{\omega_c C} = -j4\omega_c L$$

$$f_c = \frac{1}{4\pi\sqrt{LC}}$$



**Procedure:** The LC Low pass filter is connected as shown in figure.

Low pass filter:

In put voltage of 1V and frequency 50Hz from a sine wave generator is applied across the input terminals. A load resistance equal to the characteristic impedance is connected across the output terminals. The output voltage is measured across this resistor. This is repeated in for different frequencies in steps of 50Hz well beyond cut-off and the readings are tabulated.

A graph is plotted taking frequency on X axis and output voltage on Y-axis. The calculated cut off frequency is compared with the observed value.

In case cut off frequency and characteristic impedance are given Z1 and Z2 is calculated and the circuit is assemble and frequency response of the circuit is studied.

High pass filter :

The observed cut-off frequencies are compared with frequencies calculated using the formulae

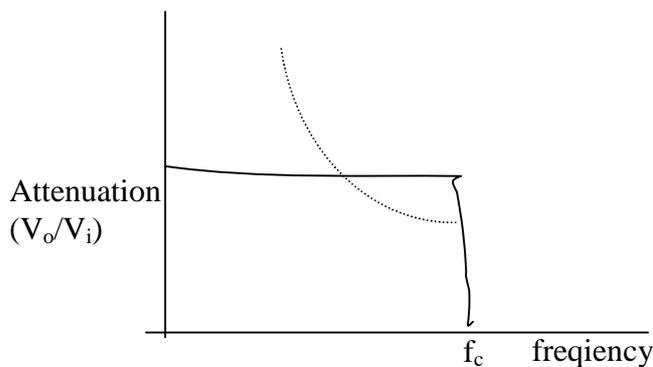
For high pass filter  $f_c = 1/4\pi\sqrt{LC}$  Hz

For low pass filter  $f_c = 1/\pi\sqrt{LC}$  Hz

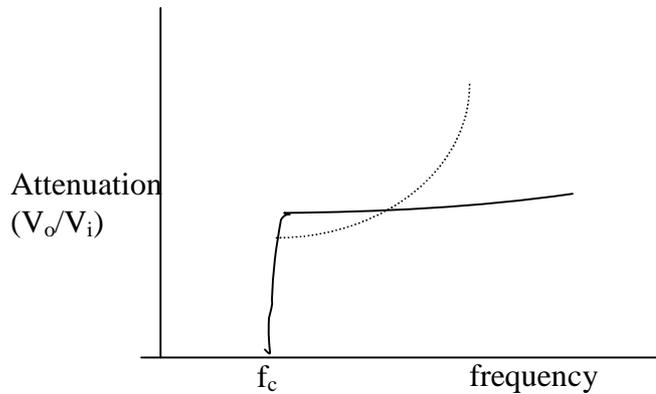
In the next step the in put voltage of the A.F. signal generator is kept constant at 1 volt. The output is measured across the resistor. This is repeated in each case i.e. in LC low pass and high pass filters and the readings are tabulated.

**Graphs:**

For ideal low pass filter



For ideal high pass filter



### Observations:

For Low pass filter:

S.No.	Frequency(kHz)	Input Voltage ( $V_i$ )	Out put Voltage ( $V_o$ )	Attenuation ( $V_o/V_i$ )
1				
2				
3				
4				
5				

For High pass filter:

S.No.	Frequency (kHz)	Input Voltage ( $V_i$ )	Out put Voltage ( $V_o$ )	Attenuation ( $V_o/V_i$ )
1				
2				
3				
4				
5				

### Precautions:

1. The generator impedance must be equal to the characteristic impedance of the network.
2. The voltages must be measured with high impedance multimeters.
3. The coils must be selected such that they have almost equal value of inductance.
4. If output voltage must be less than input voltage as there is no amplifier in between. However if there is mismatch, spurious values may be recorded and this has to be avoided.

**Result:** The frequency response of the constant –K high pass and low pass filters are studied.

For LC High Pass Filter:

Cut off frequency theoretically - Hz

Cut off frequency practically - Hz

For Low pass Filter:

Cut off frequency theoretically - Hz

Cut off frequency practically - Hz

## Experiment No. 7

**ULTRASONIC INTERFEROMETER****Aim: -**

(a) To determine ultrasonic velocity in liquids using Ultrasonic Interferometer.

(b) To determine adiabatic compressibility of given liquid.

**Apparatus: -**

Ultrasonic Interferometer, Micrometer, cell, noncorrosive liquids like Benzene ( $C_6H_6$ ), Carbon tetrachloride ( $CCl_4$ ), distilled water, measuring jar and beaker.

**Working principle:**

An ultrasonic interferometer is a simple and direct device to determine the ultrasonic velocity in liquids with a high degree of accuracy. The principle used in the measurement of velocity  $v$  is based on the accurate determination of the wavelength  $\lambda$  in the medium. Ultrasonic waves of known frequency ( $f$ ) are produced by large piezoelectric crystal coated corrosive resistant conducting material like gold with fixed at the bottom of the cell. These waves are reflected by the movable the metallic plates kept parallel to the piezoelectric crystal. If the separation between the two plates is exactly a whole multiple of the sound wavelengths, standing waves are formed with in the medium. This acoustic resonance gives rise to electric reaction on the generating piezoelectric crystal and the anode current of the generator become maximum.

If the distance is now increased or decreased, whenever the variation is exactly one half wavelength ( $\lambda/2$ ) or multiples of it, anode current becomes maximum at those points. The knowledge of separation between two alternate maxima is the wavelength ( $\lambda$ ) of ultrasonic wave gives the velocity  $V$  by the relation  $V = \lambda f$

**Description: -**

The Ultrasonic Interferometer consists of two parts

- i) The high frequency generator that drives the piezoelectric crystal.
- ii) The measuring cell with a movable plate 12c.c of liquid is required to fill the cell.

**The high frequency generator: -**

The high frequency generator consists of 2MHz crystal controlled oscillator and produces a high frequency. The H.T current to the output is fed, through a bridge network including a microammeter in such a way that the changes in the plate current can be observed on the microammeter. There are two controls, of these one is used for sensitivity regulation and other for initial current adjustments.

**The measuring cell: -**

This is connected to the high frequency generator through a shielded cable. In order to perform the experiment at high temperatures a heat jacket is provided. Heating liquid is circulated through the liquid jacket around the liquid chamber.

A piezoelectric crystal is fixed horizontally at the bottom of the measuring cell. The Ultrasonic waves move normally from this crystal and is reflected back from the movable plate. Standing waves are formed in the liquid, in between the reflected plate and piezoelectric crystal. This reflector plate can be raised or lowered by means of a micrometer screw reading up to 0.001cm, keeping its plane parallel to the quartz crystal.

### Procedure: -

#### (a) Determination of ultrasonic velocity in liquids:

The experimental liquid is poured in to the cell. The micrometer screw is slowly moved up and down till the microammeter shows a maximum and the reading is noted. The distance between the crystal and the reflected plate is now an integral multiple of the half wavelength of the wave. Now moving the screw displaces the reflector plate and the Position of the next maxima is noted. Like this five or six readings are noted and their readings are tabulated. The total distance moved by the reflector is then given by  $d = n \cdot \lambda / 2$  where  $n$  is the no. of maximas, wavelength  $\lambda$  can be calculated from the notation  $\lambda = 2 \cdot d / n$

The frequency  $f$  of the high frequency generator is 2 M Hz. (in the present case); the velocity  $V$  of Ultrasonic waves in the liquid can be calculated according to relation

$$\text{Velocity} = \text{wavelength} \times \text{frequency. } V = \lambda f$$

#### (b) Determination of adiabatic compressibility of given liquid

1. Determine the ultrasonic velocity of the given liquid at room temperature using the above method.

2. Determine the density ( $\rho$ ) of the liquid following any standard method. Check whether it is agreeing with the standard value given in the Lange's tables.

3. The adiabatic compressibility is related to the Ultrasonic velocity by the relation

$$V = \sqrt{\frac{1}{\beta_{ad} \rho}}$$

Taking the ratio of specific heats as known (for any standard liquid), the isothermal compressibility can be determined from the relation

$$V = \sqrt{\frac{\gamma}{\beta_{iso} \rho}}$$

Ex: For benzene

	Standard values at temp $t^{\circ}\text{C}$	Calculated values at temp $t^{\circ}\text{C}$
d		
$\gamma$		
$\beta_{\text{iso}}$		
$\beta_{\text{ad}}$		

$\beta_{\text{ad}}$  and  $\beta_{\text{iso}}$  at different temperatures can be obtained by measuring ultrasonic velocity in the given liquid at various temperatures.

### Observations:

Least count of the micrometer screwgauge LC =

S.No.	MSR (a)	PSR X LC (b)	a+b	Distance (d)	$\lambda = 2d/n$

### Precautions:

- i) Do not switch on the equipment with the interferometer cell empty.
- ii) Do not switch on the equipment unless the shielded R.F cable is connected to the interferometer cell
- iii) After using the cell, drain out the liquid and wash the cell with suitable solvent and then with distilled water and completely dry the cell.
- iv) Clean the cell with cotton. If there is any sediment, wash the cell with benzene or acetone to remove them. After that use water to flush any remaining matter. Dry the cell and then fill with experimental liquid.
- v) Do not use the liquids which may react with the crystal plating or the cell walls.
- vi) Do not move the micrometer screw forward and backward quickly as this will produce backlash error. Move the screw slowly in one direction only until all the readings are taken.

### Result:

The velocity of given liquid is .....

The adiabatic compressibility is measured to be .....

Experiment No. 8

### DIELECTRIC CONSTANT OF A LIQUID

**Aim:-** To study the variation of dielectric constant of a given liquid (benzene) with changing the concentration by adding a polar liquid say nitrobenzene to benzene.

**Apparatus:** Capacitor, Beaker, digital L-C-R meter, measuring jar, Carbon tetra Chloride ( $\text{CCl}_4$ ), Benzene, Nitrobenzene, etc

**Principle:-**

The dielectric constant of a liquid is calculated by the formula,

$$\epsilon = \frac{\text{capacitance in dielectric medium}}{\text{capacitance in air}}$$

**Formula:**

Dielectric constant

$$k = \frac{c_d - x}{c_a - x}$$

Where  $c_d$  = capacitance in dielectric medium

$c_a$  = capacitance in air

$x$  = lead capacitance

Lead capacitance :

$$x = \frac{\epsilon c_a - c_d}{(\epsilon - 1)}$$

**Procedure:-**

The gang condenser is checked whether it is shorted or performing well. A well performing gang condenser is taken in such a manner that the capacitance of the gang condenser should lie in the range of L-C-R meter. The capacitance range is adjusted to certain position in LCR meter and the capacitance in air is measured using L-C-R meter.

Now a known volume of  $\text{CCL}_4$  is taken in a beaker and the capacitor is dipped in  $\text{CCL}_4$  and the capacitance ( $C_d$ ) is measured. The value of lead capacitance is calculated using the formula

$$x = \frac{\epsilon c_a - c_d}{(\epsilon - 1)}$$

By taking the condenser out of the jar, is exposed to air until the total  $\text{CCL}_4$  is evaporated. Then again the capacitor is placed in a known volume of benzene and its capacitance is measured. 5 ml of Nitrobenzene is added to benzene and the value of capacitance is noted.

The dielectric constant of medium is given by

$$k = \frac{c_d - x}{c_a - x}$$

By noting down the densities of the dielectric media of benzene and nitrobenzene, the mass fraction of nitro benzene can be calculated by the formula,

$$\text{Mass fraction} = \frac{\text{volume of } (C_6H_5NO_2) \times \text{density of } (C_6H_5NO_2)}{\text{volume of } (C_6H_6) \times \text{density of } (C_6H_6)}$$

Varying mass fraction of nitrobenzene, dielectric constant of mixture is measured.

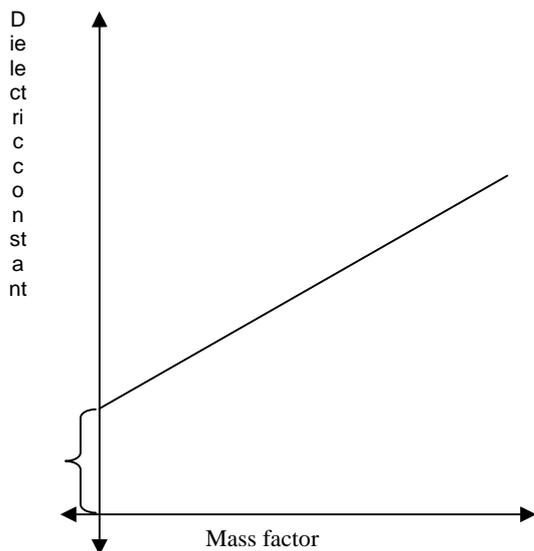
**Observations:**

S.no	Volume of $C_6H_6$ (ml)	Volume of $C_6H_5NO_2$ (ml)	Capacitance ( $C_d$ )	Dielectric constant (k)	Mass fraction (M)

**Graph:-**

A graph is drawn by taking mass fraction along the x-axis and the dielectric constant along y-axis which is a straight line from the graph we can see the variation of dielectric constant of benzene addition of nitrobenzene.

Dielectric constant of liquid



**Precautions:-**

1. The capacitance of the condenser in all cases should lie the range of

L-C-R meter.

2. the capacitor should be completely immersed in the particular liquid . the liquid should be taken in such a way.

**Result:-**

The variation of the dielectric constant of liquid benzene is studied by changing the concentration of polar liquid nitro benzene.

Experiment No.9

### VARIATION OF MAGNETIC FIELD

**Aim:** To determine the magnetic field between the pole pieces of an electromagnet and to study the variation with current and distance

**Apparatus:** Electromagnet, Power supply, Gauss meter, Hall probe, Variac

**Principle and Theory:** The magnetic field between pole pieces depends upon

- 1) Current passing through the coils
- 2) The distance between pole pieces and
- 3) The material of pole pieces.

The magnetic field is measured using Gauss meter based on “Hall effect” of a semi conducting material like Indium, Arsenic, etc. When current is passed in a rectangular block of material placed in a magnetic field perpendicular to the current direction a voltage developed in a direction, which is perpendicular to the both magnetic field and current.

Hall voltage  $V_H$  is given by  $V_H = R_H I_H \times B$   
 Where  $R_H$  is Hall coefficient  
 $I_H$  is Hall current  
 $B$  is magnetic field.

The Gauss meter is based on the above principle. The gauss meter directly reads ‘B’. The magnetic field is found for different currents in steps of 0.5 Amp from 0.5 Amp to 2.5 Amp.

**Procedure:** The current passing through the magnet is varied using a variac. A gauss meter is switched and the ‘zero’ on the meter is adjusted using ‘O’ control keeping the probe out side the magnetic field. Then the probe is fixed at center of pole pieces. The magnetic circuit is closed and the current through electromagnet is adjusted to be 0.5Amp using variac. The corresponding magnetic field is noted. The current in the electromagnet is increased in steps of 0.5 Amp to 2.5 Amp. For different distances, the current and magnetic field readings are taken and tabulated as shown in table.

S.No.	Distance in ‘mm’	current $I_H$ (Amp)	Magnetic field (Gauss)
1.	10	0.5	
		1.0	
		1.5	
		2.0	
		2.5	

-----

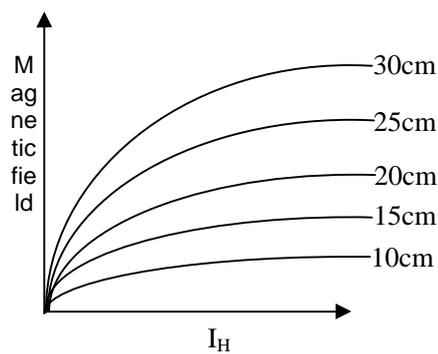
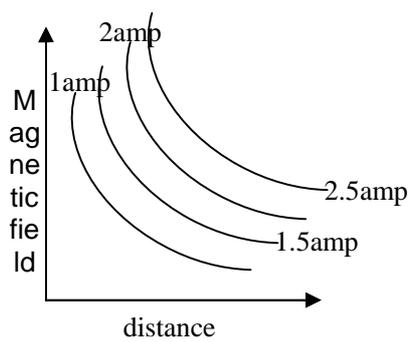
2. 15  
0.5  
1.0  
1.5  
2.0  
2.5

3. 20  
0.5  
1.0  
1.5  
2.0  
2.5

4. 25  
0.5  
1.0  
1.5  
2.0  
2.5

5. 30  
0.5  
1.0  
1.5  
2.0  
2.5

**Graph:** A graph is drawn between (1)  $I_H$  and magnetic field and (2) magnetic field and distance between pole pieces.



**Precautions:**

1. The current through the magnet is checked before and after the experiment.
2. The magnetic field is measured either when the current is decreased or increased, as there will be hysteresis in material of pole pieces.
3. The Hall probe is handled very carefully to avoid damage.

**Result:** The magnetic field increases with current and the field decreases with distance.

Experiment No.10

## TEMPERATURE COEFFICIENT OF PLATINUM

**Aim** :- To determine the temperature coefficient of platinum and find the melting point of wax using pt-100.

**Apparatus** :-Pt-100 probe, resistance meter, heating bath. Thermometer.

**Principle** :- In general , the variation of resistance is not linear and can be given by the relation

$$R_t = R_o(1+\alpha t+\beta t^2)$$

Where  $R_t$  = Resistance at temperature T

$R_o$  =Resistance at  $0^{\circ}\text{C}$

$\alpha, \beta$ 's are constants

But in the case of platinum, the constant  $\beta$  negligibly small and hence the resistance varies linearly over a wide range of temperature .The temperature coefficient of resistance  $\alpha$  is given by the equation

$$\alpha = (R_t - R_o) / R_o t$$

The linear variation of resistance is used to measure the temperature in a platinum resistance thermometer using a calibration graph.

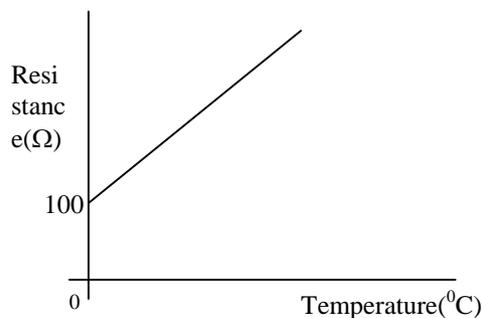
Pt-100 probe consists of a fine wire of platinum embedded in a ceramic probe .The resistance is  $100 \Omega$  at  $0^{\circ}\text{C}$  .

**Procedure**:- The probe is inserted in to a heating block of all which also contains a hole to insert a thermometer .The block is heated electrically . As the temperature increases resistance increases. It is measured using a bridge circuit or accurate ohmmeter in the intervals of  $5^{\circ}\text{C}$  up to  $100^{\circ}\text{C}$

A graph is drawn with temperature on X-axis and resistance on Y-axis . The graph is linear. From the gradient of the graph  $\alpha$ , the temperature coefficient of resistance is obtained as shown in figure(1) .

Take bee wax(200gm) into a small aluminium container and heat (using hot plate)it to melt. Put the tip of Pt-100 probe into the melt and cool it . Observe the temperature while the melt solidifies. Measure the resistance of Pt-100 probe and from the graph note the corresponding temperature. Record your observed temperatures. Repeat the experiment, number of times and calculate the average melting point of bee wax.

**Graphs**:-



**Observations:**

Temperature versus resistance

S.No	Temperature	Resistance (ohm)

Determination of melting point using wax:

Temperature versus resistance

S.No	Resistance (ohm)	Temperature

**Precautions:-** (I) Thermometer readings are taken carefully.**Result:-** Temperature coefficient of resistance of PtStandard value  $\alpha = 0.00385 / ^\circ\text{C}$ Observed value  $\alpha =$ 

Melting point of wax =

## Experiment No.11

### **e /m by Thomson's method**

**Aim** :- To determine the charge to mass ratio of the electron by Thomson's method.

**Apparatus**:-Thomson's method apparatus, short bar magnet.

**Principle** :- The method involves the balancing the beam deflected by electric force and magnetic force, these forces are applied on the electron beam in a cathode ray tube. The deflection depends up on electric field 'E' and the magnetic field 'H' and on the geometrical parameters of cathode ray tube.

**Formula** :-

$$e/m = \frac{v y}{d H^2 l L} \cdot 10^7$$

V= deflecting voltage.

Y= deflection of the spot.

d= separation of deflecting plates.

H= magnetic field

l= length of deflecting of plates

L =distance between screen from plates.

The vertical deflection on the screen y is noted next the magnets are placed symmetrically on each side of the arms keeping the distance on either side equal. The distance is adjusted so that the spot retraces the original position .the distance is noted ,varying the deflecting voltage, the distances are noted.

In the second part the magnetic field for the distance 'r' is measured. For this cathode ray tube stand is removed and in its, place a deflection magnetometer is replaced in such away that the center lies along the arms keeping the magnets away the pointer is adjusted to reach zero.

Now the magnets are placed exactly at the same distances as in the first part. For each position the pointer reading  $\theta_1$  and  $\theta_2$  are noted. Now the polarity of the magnets are reversed and again the deflections  $\theta_3$  and  $\theta_4$  are noted. The average ' $\theta$ ' is taken.

**Procedure** :- It consists of two parts,

In the first part the electric and magnetic forces are balanced. In the second part the magnetic field applied is measured. In the first part the wooden stand on which the cathode ray tube is mounted, is placed so that the axis is in north-south direction and arms in east-west direction. The cathode ray tube is connected with power supply limit. The unit switched on .The power intensity and focus controls are Adjusted to get a clean spot . Now a deflecting voltage (v) is applied

The magnetic field is calculated using,

$$H = H_e \cdot \tan\theta \quad , \quad H_e - \text{earth's magnetic field}$$

**Observations :**

S.No	Deflecting Voltage (volts)	Distance of the bar magnet (cm)	Deflection of spot

S.No	Distance	$\theta_1$	$\theta_2$	$\theta_3$	$\theta_4$	$\theta_{avg}$	$\tan\theta_{avg}$	$H_e \tan\theta_{avg}$

Constants of CR- tube :-

separation between the plates  $d =$

length of deflecting plates  $l =$

distance of screen from plates  $L =$

**Precautions:**

1. while taking the point readings parallax error should be avoided
2. while changing the polarity of the magnets, the magnets should be placed exactly at the previous position.
3. The angle of deflection( $\theta$ ) should lie between  $30^\circ$  to  $60^\circ$

**Result:** - the charge to mass ratio of electron by Thomson's method is verified



**Experiment No.12**

**TWIN – T FILTER**

**Aim:** To study the frequency response characteristics of Twin – T – filter circuit and to find its cut off frequency.

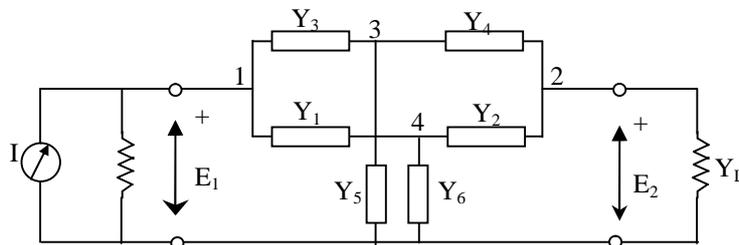
**Apparatus:** AF signal generator, capacitors, Resistances, Multimeter and connecting wires.

**Formula:**

Cut off frequency =  $1/2\pi RC$  Hz

Where C is capacitance in microfarads, R is resistance in Ohms.

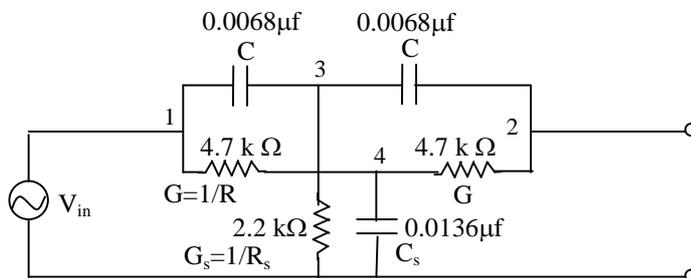
**Circuit:**



**Theory:** The Twin – T – Filter is used as a good frequency selector. Here the Twin-T-Filter consists of capacitors and resistors as shown in the FIG. Here by observing the circuit carefully we find that there are two T-type filters. So, this circuit is named as Twin-T-Filter. Here the in put kept constant and in every step out put decreases first and increases in the second phase.

The twin-T circuit exhibits a selectivity curve which may closely resemble that of the antiresonant circuit, and interestingly enough this curve may be obtained without the use of inductance. Furthermore, the effective Q can be made much greater than that obtainable in the usual antiresonant circuit.

This selective property of the twin-T network is used so often in practice that it is well worth investigating. It is usual in this application to use equal resistance’s for the Y1 and Y2 elements, equal capacitance’s for Y3 and Y4, resistance for Y5, and capacitance for Y6. Thus, for the circuit Have shown in fig (1)



$Y_1 = Y_2 = G, Y_3 = Y_4 = j\omega C, Y_5 = G_s, Y_6 = j\omega C_s$

Then, substituting into the equation of null

$Y_3 Y_4 (Y_1 + Y_2 + Y_6) + Y_1 Y_2 (Y_3 + Y_4 + Y_5) = 0$

$$-(\omega_0 C)^2(2G + j\omega_0 C_s) + G^2(j2\omega_0 C + G_s) = 0$$

where  $\omega_0$  is  $2\pi$  times the null frequency. Then, equating reals,

$$2(\omega_0 C)^2 G = G^2 G_s$$

and imaginaries

$$(\omega_0 C)^2 \omega_0 C_s = 2\omega_0 C G^2$$

hence, from the last two equations, the null frequency may be determined for

$$\omega_0^2 = \frac{GG_s}{2C^2} = \frac{2G^2}{C_s C}$$

Thus given the circuit components, it is possible to determine the frequency at which the null occurs.

In order to simplify the procedure, it is convenient to define a design parameter  $n$  in the following manner: Rearranging the two right-hand members of above equation

$$n = \frac{G_s}{2G} = \frac{2C}{C_s}$$

then  $\omega_0^2$  becomes

$$\omega_0^2 = \frac{GG_s}{2C^2} = \frac{G}{2C^2} 2Gn = n \frac{G^2}{C^2}$$

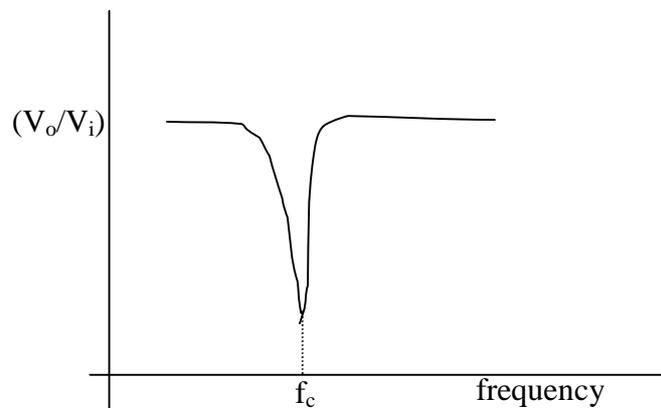
$$\omega_0 = \frac{\sqrt{n}}{RC}$$

It is found that  $n=1$  gives the most selective curve.

Then the cut off frequency of the circuit is given by  $f_c = 1/2\pi RC$  Hz where  $R$  is resistance in ohms and  $C$  is Capacitance in microfarads.

**Procedure:** The circuit connections are made as shown in the FIG 2. The output of the AF signal generator is kept constant (1 volt). Now keeping generator voltage constant increases the frequency and the output voltage is taken at each stage.

**Graph:** A graph is drawn between frequencies and gains taking frequencies on X-axis and gain on Y-axis.



**Observations:**

S.No	Frequency (kHz)	Input voltage $V_I$ (volts)	Output voltage $V_o$ (volts)	Gain ( $V_o/V_I$ )

**Precautions :**

1. All the connections must be made as per the circuit given.
2. The observations are taken carefully.
3. The input voltage must be kept constant for each measurement.

**Result :**

The frequency response characteristics of Twin-T-filter are studied and the cutoff frequency is

$f_c(\text{theoretical}) =$

$f_c(\text{Experimental}) =$