KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)
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Coimbatore - 641021.
(For the candidates admitted from 2017 onwards)

SUBJECT : ELECTROMAGNETIC THEORY (PRACTICAL) **SEMESTER** : III
SUBJECT CODE: 17PHU313 **CLASS** : I B.Sc.PHYSICS

SEMESTER – III

17PHU313	ELECTROMAGNETIC THEORY (PRACTICAL)	L T P C
		- - 4 2

Any 8 experiments

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection, refraction of microwaves
7. To study Polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan`s law of radiation and to determine Stefan's constant.

12. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

REFERENCE BOOKS

Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.

Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal

Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

List of Experiments

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2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
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5. To study the reflection, refraction of microwaves
6. To study Polarization and double slit interference in microwaves.
7. To verify the Stefan`s law of radiation and to determine Stefan's constant.
8. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

Experiment No -1 Date:

MALUS LAW

OBJECT:-To verify the Law of Malus for plane polarized light with the help of photovoltaic cell.

APPARATUS REQUIRED -

Optical bench, halogen lamp, double convex lens, polarizer, analyzer, photo voltaic cell with colorimeter and micro-ammeter (0-50mA).

FORMULA USED -

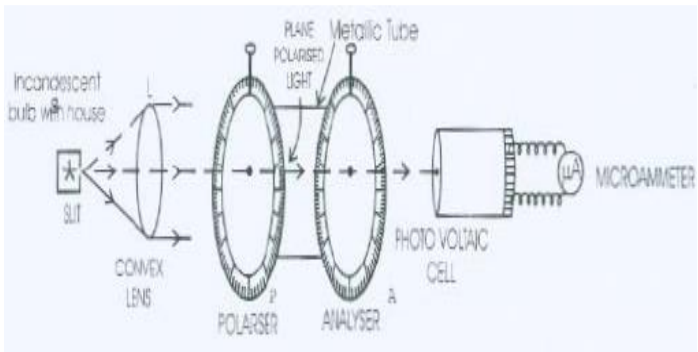
According to Malus Law, when a beam of completely plane polarized light is incident on the analyzer, then the intensity I of the emergent light is given by

$$I = I_o \cos^2 \phi$$

Where I_o = Intensity of plane polarized light incident on the analyzer.

Φ= angles between planes of transmission of polarizer and the analyzer

To verify this law, light from the analyzer is made to enter in a photovoltaic cell. The current output of photovoltaic dell is connected to microammeter.



PROCEDURE:-

1. The experimental setup is arranged as shown in the figure. In this arrangement, the source S, convex lens, Polarizer P, Analyzer A and the window of Photovoltaic cell should be at the same height.
2. Now switch on the incandescent bulb. Light from the source S rendered parallel with the help of convex lens L is allowed to fall on polarizer P.
3. For any orientation of the polarizer P, the polarized light passes through analyzer A. The analyzer A is rotated till there is maximum deflection in the micro-ammeter. The position of analyzer is noted on the circular scale. The corresponding micro-ammeter deflection is also recorded. The position of analyzer corresponds to $\phi=0$ (here ϕ is the angle between Planes of transmission of polarizer and analyzer.)
4. The analyzer A is rotated through a small angle, say 10^o and then the steady micro-ammeter deflection is noted.
5. The experiment is repeated by rotating the analyzer through 10^o degree each time and noting down the corresponding micro-ammeter deflection till it become practically zero.

OBSERVATIONS:-

S. No.	Angles through which analyzer is rotated ϕ	Micro-ammeter reading		Cos ϕ	$Cos^2\phi$	$\theta/Cos^2\phi$
		μA	θ			
1.	10^o					
2.	20^o					
3.	30^o					
4.	40^o					
5.	50^o					
6.	60^o					
7.	70^o					
8.	80^o					

CALCULATIONS:-

Find the value of $\theta/\text{Cos}^2\phi$ from each observation and plot the graph for $\cos^2\phi$ on X-Axis and θ on Y-Axis. Discuss the nature and reason for such a graph.

SOURCES OF ERROR AND PRECAUTIONS:-

1. The position of the polarizer should not be disturbed throughout the experiment.
2. The source of light, lens, polarizer, analyzer, and the solar cell should be adjusted to the same height.
3. The voltage applied to the light source should be constant throughout the experiment.
4. The experiment should be performed in the dark room to avoid any external light inside the photovoltaic cell.
5. Care should be taken while performing the experiment as the bulb becomes very hot

Result: The Law of Malus for plane polarized light with the help of photovoltaic cell is verified

Experiment No -2 Date:

Object: To determine the specific rotation of a cane sugar solution.

Apparatus

1. Polarimeter
2. Solution tube filled with the given solution

Formula

$$(\alpha) = \frac{\theta}{lc}$$

where α = Specific rotation; l = Length of the solution tube in dm, θ = Rotation in degrees

Procedure

1. Switch on the power of the polarimeter instrument.
2. Illuminate the sodium lamp (yellow light) at maximum emmission. The light will pass through the solution tube.
3. Make an experiment with the distilled water. It will be filled in the tube.
4. Rotate the polarimeter using the rotating nob (see it at the bottom of the circular scale in
.
5. First keep the eyepiece focused on the maximum intense yellow strip, and after rotation of the polarizer check the appearance of the intense black-strip at the same place. You will not note the corressponding scales of these two positions. This is just to examine the focus of the eyepience for the incoming polarized light.
6. Now again keep the eyepiece focused on the position where yellow or black strip was seen with maximum contrast, and then

slightly rotate the analyzer. Once the yellow or black strip disappears, i.e., fades against the background and less intense and almost uniform field-of-view appears, note the reading of circular scale as well as vernier scale.

7. The polarizer plate consists of equal brightness of two component of polarized light at this point, so the field-of-view appears almost uniform. By slightly rotating it either in clock-wise or anto-clockwise direction, the deviation from this condition will be observed (see the theory in Appendix).

8. Fill the solution tube now with a given concentration of sugar (10 %; 5 %; 2.5 %) and perform the above experiment again and note down the corressponding readings of the circular scale.

9. The Vernier scale has markings from 0 to 10, however, it has 20 divisions. It resembles with the 20 divisions of the circular scale (in degree). Therefore, the least count of the Vernier scale is 0.05^{o}. It should be noted that the circular scale ranges from 0^{o} to 180^{o}.

10. The circular scale reading is that how many its divisions already passed from the zeroth of the Vernier scale. Note that reading in the table. While, for the reading of Vernier scale we see the division of this scale which matches exactly with the division of circular scale. We multiply that division of Vernier scale with its least-count and add in the reading of the main circular scale.

11. θ_1 is the difference between the reading of the first position on the circular scale for the sugar solution to the same for the distilled water. Similarly, θ_2 is the difference between the reading of the second position on the circular scale for the sugar solution to the same for the distilled water.

12. Mean θ is estimated as $\theta_1 + \theta_2 / 2$, which is the angle of the rotation of the plane of polarization of the light, when it passes through the solution.

4 Observations

1. Room temperature = ... ^{o}C.

2. Length of the solution tube = ... dm.

3. Mass of the sugar dissolved = ...gm.

4. Volume of the solution = ...in c.c.

Figure 1: Left-panel : Polarimeter instrument and its set-up. Right-panel : Place of the solution tube in the instrument

<table>
<tr><td colspan="13">Reading on Analyzer for Equal Illumination in Degrees</td><td colspan="2">Rotation in Degrees</td></tr>
<tr><td colspan="6">With distilled water</td><td colspan="7">With sugar solution</td><td colspan="2"></td></tr>
<tr><td colspan="3">First position</td><td colspan="3">Second position (180° apart)</td><td rowspan="2">Strength of the solution per 100 c.c.</td><td colspan="3">First position</td><td colspan="3">Second position (180° apart)</td><td rowspan="2">Angle (θ_1)</td><td rowspan="2">Angle (θ_2)</td></tr>
<tr><td>Main Scale</td><td>Vernier</td><td>Total</td><td>Main Scale</td><td>Vernier</td><td>Total</td><td>Main Scale</td><td>Vernier</td><td>Total</td><td>Main Scale</td><td>Vernier</td><td>Total</td></tr>
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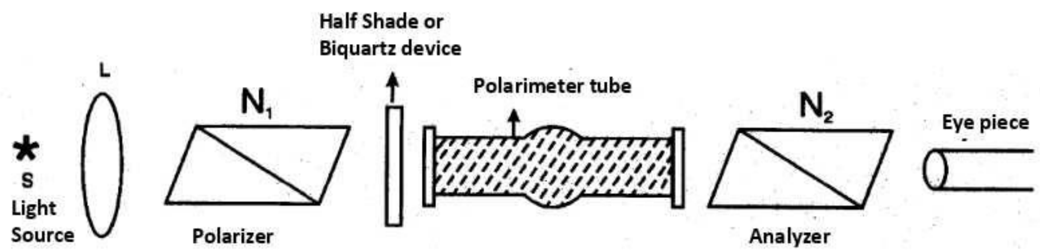

Figure 3: Schematic of the Experiment

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Calculation

Result: The specific rotation (α) of the cane sugar (for a given concentration per decimeter) solution at is ....^{o}

Experiment No -3 Date:

ULTRASONIC INTERFEROMETER

Aim

To determine the velocity of ultrasonic waves in a given liquid and also to determine the compressibility of the liquid

Apparatus required

Ultrasonic interferometer, measuring cell, frequency generator, given liquid, etc

Formula

Velocity of Ultrasonic waves in the given liquid, $v = \lambda f$

Compressibility of the given liquid, $K = 1/v^2 p$

where $\lambda = 2d/n$ is the wavelength of the Ultrasonic wave in m
f is the Frequency of Ultrasonic waves in Hz
d is the distance moved by the micrometer screw in m
n is the number of oscillations *p* is the density of the given liquid in kgm^{-3}

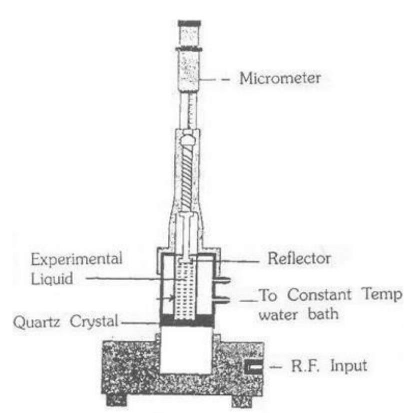
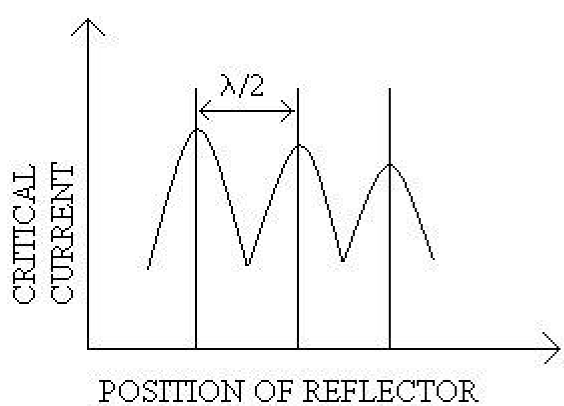


Figure 1

Fig. 1 Ultrasonic interferometer

Procedure

The measuring cell is connected to the output terminal of the high frequency generator through a shielded cable. The cell is filled with the experimental liquid before switching ON the generator. Now, when the frequency generator is switched ON, the Ultrasonic waves move normal from the Quartz crystal till they are reflected back by the movable reflector plate. Hence, standing waves are formed in the liquid in between the reflector and the quartz crystal.The distance between the reflector and crystal is varied using the micrometer screw such that the anode current of the generator increases to a maximum and then decreases to a minimum and again increases to a maximum. The distance of separation between successive maximum or successive minimum in the anode current is equal to half the wavelength of the Ultrasonic waves in the liquid. (see Fig.2). Therefore, by noting the initial and final position of the micrometer screw for one complete oscillation (maxima—minima—maxima) the distance moved by the reflector can be determined



To minimize the error, the distance (d) moved by the micrometer screw is noted for 'n' number of oscillations (successive maxima), by noting the initial and final reading in the micrometer screw and is tabulated. From the total distance (d) moved by the micrometer screw and the number of oscillations (n), the wavelength of ultrasonic waves can be determined using the formula $\lambda = 2d/n$. from the value of k and by noting the frequency of the generator (f). The velocity of the Ultrasonic waves and compressibility of the given liquid can be calculated using the given formula.

Calculation

(i) Wavelength of the Ultrasonic waves
(ii) Frequency of Ultrasonic waves
(iii) The velocity of Ultrasonic waves in the given liquid, v
(ii) Density of the given liquid (□)
The Compressibility of the given liquid, □□

Velocity of Ultrasonic waves in the given liquid, $v = \lambda f$

Compressibility of the given liquid, $K = 1/v^2$ p

Result

1. Velocity of ultrasonic waves in the given liquid, v =
2. Compressibility of the given liquid, K =

Experiment No -4 Date:

Stefan`s law of radiation and to determine Stefan's constant

OBJECTIVE: To verify Stefan's law and to determine Stefan's constant by electrical method.

APPARATUS: 6V battery, D.C. Voltmeter, D.C. ammeter, Electric bulb (having tungsten filament) of 6V, 6W, Rheostat (100 ohm).

FORMULA USED:

$$Log_{10}P= \alpha Log_{10}T + Log_{10}C$$

Where, P = Total power emitted by a body at temperature T,

α = power of T close to 4

T = temperature of a body

C = some constant depending on the material and area of such a body.

PROCEDURE:

1. Make the connections as shown in the figure. In order to connect voltmeter across the bulb, the two wires are soldered to the base points of the bulb.

2. With different increasing and decreasing values of current, we adjust such that the bulb glows each time. Then for value of V and I, ratio V/I is found which gives R_g. This is the filament resistance at 800K. From R_t/R_0 vs. T graph, we note that

$$R_t/R_0 = R_{800}/R_{273} = 3.9$$

Therefore $R_{800}/3.9 = R_{273}$

Or $R_g/3.9 = R_0$

Graph R_t/R_0 vs. T is to be provided to the student (see table3).

3. Now filament current I is increased from a value below glow stage to values high enough to get dazzling white light, measuring voltage V across bulb every time. From these V and I values, we deduce power P (=VI) and R_t (=V/I). From R_t using the value R_0 (or R_g /3.9) or R_{273K} , we deduce the temperature T of the filament and obtain a graph in $Log_{10}P$ against $Log_{10}T$.

Observations:

S.No.	Current Increasing			Current Decreasing		
	Voltage V volts	Current I amp.	R_g=V/I Ohms	Voltage V volts	Current I amp.	R_g=V/I Ohms
1 2 3 4						

Table 2. Determination of Power P: for different temperature T

S.No.	Pot. Diff. v volts	Current I amp.	R_t=V/I Ohms	R_t/R_o	Temp.From Table 3 or from graph K	$Log_{10}T$	Power P = V I Volts	$Log_{10}P$
Min. 10 values								

Table 1. For plotting Rt/Ro versus T graph

Temp. in O^0C	R_t/R_o
0 100 200 300 400 500 600 700 800 900	

1000 1100 1200 1300 1400 1500	

CALCULATIONS:

Slope =AB/BC = α

RESULT: Plotted the graph between $\log_{10}P$ vs. $\log_{10}T$ and the Stefan`s law of radiation is verified. The Stefan's constant is…….

Experiment No -5 PN junction diode-Boltzmann constant Date:

Aim

Determination of Boltzmann constant using a PN junction diode.

APPARATUS

PN junction diode, Battery

FORMULA USED

$$I_s = A_e E_g / \nu K_B T$$

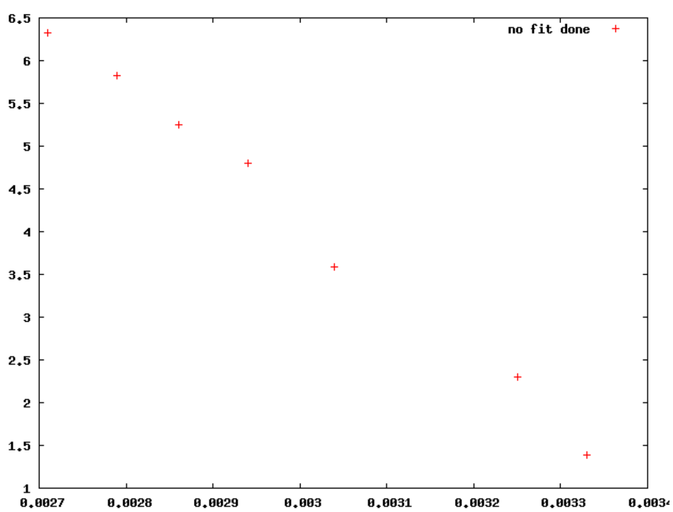
Where A is nearly constant independent of temperature and dependent on dif- fusion coefficients of electrons and holes. E_g is the band gap of the semiconductor, k_B is the Boltzmann constant. ν is a constant; 1 for germanium and 2 for silicon; and T is the absolute temperature. Band gap of silicon is 1.12eV and that of germanium 0.66eV.

Procedure

Connect the circuit as shown below. The circuit involves a PID controlled oven, diode and a power supply. Using the PID controlled oven, increase the temperature in small steps starting from room temperature and note the value of saturation current I_S. Now, plot a graph of $\ln I_S$ versus 1/T and calculate the slope. From this the Boltzmann constant can be calculated.

Table

S.no	Temperature T	Saturation Current I_S μA
1		
2		
3		
4		
5		



From the calculation for the slope, the Boltzmann Constant is calculated

Result:

The Boltzmann Constant by PN junction diode is……..

Experiment No -6 Reflection, Refraction of microwaves Date:

Aim

To study the reflection, refraction of microwaves

Apparatus

- Plane mirror (front-surfaced)
- Thick glass prism
- Pin-board and hat pins
- Protractor, straight-edge,plane sheets of clean 81/2” × 11” paper

Procedure

Part 1: Angles of Incidence and Reflection

Please do not touch the mirror surfaces.

Note that the mirror is “front-surfaced”; light is reflected from its front sur- face In household mirrors, the silvering is placed on the back of a sheet of glass and sealed in so that the reflecting surface will last for years and years. In front-surfaced mirrors, the light rays don’t have to pass through the glass first in order to be reflected.

1. Draw a line down the centre of a piece of clear paper and place it on the pin-board. Set the mirror surface against this line near the centre of the page, standing on edge. On the front side of the mirror, off to one side, stick a hat-pin vertically into the pin-board to serve as an object. Viewing the image of this pin in the mirror, place two hat pins along the direction of a reflected ray. Keep the two pins as far apart as possible.
2. Remove the pins, and circle these three holes in the paper.
3. Repeat this procedure once more for another viewing direction, using something other than circles to mark the other set of holes.
4. From each of the two sets of pin-holes you have the direction of the reflected ray, which you can extend to find the point of reflection at the mirror. From the point of reflection and the object pin hole, you can draw the incident ray direction. Remove pins, mirror and sheet, and draw in all incident and reflected rays and the surface normal at each point of reflection. Measure the incident and reflected angles for each of the rays and enter them in Table 3.1.

Part 2: Virtual Images

1. Begin with paper, line, and mirror as in the previous part. Draw a large letter V somewhere in front of the mirror. Mark the two ends of the V in some way (such as A, B, C) so that you can tell them apart in the reflection. Hint: Make the two arms of the V different lengths and it will make them easier to distinguish.
2. Place a pin in one of the strategic points of the (object) letter, (say A), and find the incident and reflected rays in two directions, labelling them (such as A_1 for the points in one direction, and and A_2 for the two points in the other direction).
3. Repeat with hat-pins placed in the other strategic points of the object letter.

4. Remove pins and mirror, and on the sheet extend each pair of reflected rays back behind the mirror as dashed lines, to where they intersect. The three intersection points thus gained mark the strategic points of the virtual image of the letter used as an object. Draw in this virtual image using dotted lines.

Part 3: Refraction through Parallel Surfaces

1. Draw a line down the centre of a piece of paper as before. With paper on the pin board, place the glass prism standing on one of its long edges, against the line, centred on the page.

2. Draw a line along the back edge of the parallel-sided glass block on the page.

3. Place a pin in the paper behind the prism off to one side. Observe from a position which will give a large angle of incidence. Use another pin on the same side of the paper so that you can map the incident ray.

4. With 2 more pins, map out the emergent ray. Remove the pins and label the 4 points.

5. Repeat the previous two steps for another object point.

6. Remove the prism.

7. Draw the incident and emergent rays for both cases, and then draw in the rays refracted through the glass as well. Measure the angles i, r, i^0 and r^0 for both rays and record them in Table 3.2. Remember that you'll have to draw in normal lines to measure the angles, or else use (90 − angle) if you measure from the glass surface. You may have to extend the rays inside the glass block in order to measure them.

Note that the emergent ray should be exactly parallel to the incident ray for each case.

Part 4: Refraction Through a Prism

1. Place the prism flat on one of its broad faces on a sheet of paper and draw in its outline carefully.

2. Place 2 pins along a path to the prism with an incident angle i about 45°.

3. Look through the side of the prism where the refracted ray emerges, and place 2 pins along the line of the emergent ray.

4. Remove the prism. Draw lines connecting both sets of pins with the faces of

the prism, and then draw the line though the prism which joins them and thus trace the ray path through the prism experimentally.

5. Measure the incident, refracted, and emergent angles and put them in Table 3.4.

ray	Angle (degrees)	
	i	r
1		
2		

Table 3.1: Light reflecting from a mirror

ray	Angle (degrees)			
	i	r	i^0	r^0
1				
2				

Table 3.2: Light refracting through a slab

ray	From incident		From emergent	
	n	Δn	n	Δn
1				
2				
average ($\bar{n}$)				
uncertainty ($\Delta\bar{n}$)				

Table 3.3: Calculated index of refraction

ray	Angle (degrees)			
	i	r	i'	r'
1				

Table 3.4: Light refracting through a prism

ray	Angle					
	r	Δr	i'	$\Delta i'$	r'	$\Delta r'$
1						

Table 3.5: Calculated refraction angles

Result: The reflection and refraction at a plane surface of microwaves are studied

Experiment No -7 Microwaves Date:

Aim

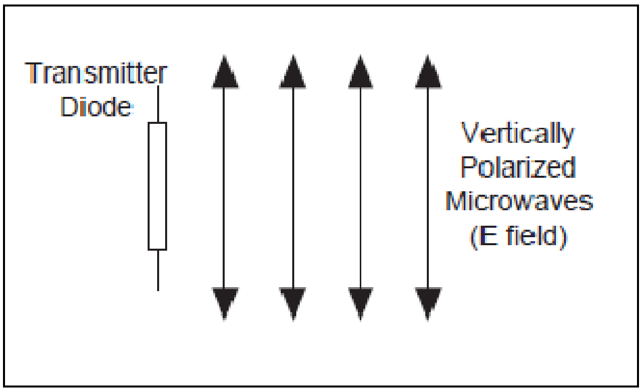
To study Polarization and double slit interference in microwaves.

Apparatus:

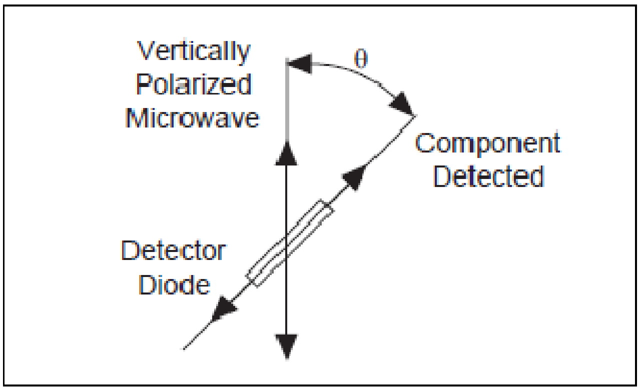
Transmitter –Receiver –Goniometer. Transmitter, Receiver - Goniometer, Rotating - Component Holder- Metal Reflectors (2) - Slit Extender Arm -Slit Spacer

Procedure

1- Arrange the equipment as shown in Figure 1.1 and adjust the Receiver controls for nearly full-scale meter deflection.
2- Loosen the hand screw on the back of the Receiver and rotate the Receiver in increments of ten degrees. At each rotational position, record the meter reading in table 2.1.
3- Note what happens to the meter readings if you continue to rotate the Receiver beyond 180-degrees?
4- Calculate M using $M=M_0\cos\theta$ where θ is the angle between the detector and Transmitter diodes and M_0 is the meter reading when $\theta = 0$.
5- Graph your data from step 2 of the experiment. On the same graph, plot the relationship $M_0\cos\theta$. Compare the two graphs.
6. Arrange the equipment as shown in Figure 3.2. Use the Slit Extender Arm, two Reflectors, and Slit Spacer to construct the double slit. (We recommend a slit width of about 1.5 cm.) Be precise with the alignment of the slit and make the setup as symmetrical as possible.
7. Adjust the Transmitter and Receiver for vertical polarization (0°) and adjust the Receiver controls to give a full-scale reading at the lowest possible amplification.
8. Set the Goniometer arm so the Receiver directly faces the Transmitter. Adjust the Receiver controls to obtain a meter reading of 1.0. Now set the angle θ to each of the values shown in table 2. At each setting record the meter reading in the table.



Vertical Polarization



Detecting Polarized Radiation

Angle of receiver	Meter reading M	$M=M_0\cos\theta$	Angle of receiver	Meter reading M	$M=M_0\cos\theta$
0			100		
10			110		
20			120		
30			130		
40			140		
50			150		
60			160		
70			170		
80			180		
90					

Angle	Meter Reading	Angle	Meter Reading
0°		45°	
5°		50°	
10°		55°	
15°		60°	
20°		65°	
25°		70°	
30°		75°	
35°		80°	
40°		85°	

Experiment No -8 Babinet's compensator Date:

Aim: To analyse elliptically-polarised light by means of Babinet's compensator

Apparatus: Babinet compensator, white light source, quarter wave plate, chock power supply, box Polaroid eye piece, reading lens, plumb line

Formula:

The phase difference between two components of elliptic vibration is given by

(□□□□□) = □L/x

L - micrometer reading for the shift with elliptically polarized light

x – micrometer reading for a phase change of □□of path change L/2.

the ratio of the axes of ellipse is given by tan □□□□a/b

Procedure

A quarter wave plate or a half wave plate produces only a fixed path difference between the ordinary and the extraordinary rays and can be used only for light of a particular wavelength. For different wavelengths, different quarter wave plates are to be used. To avoid this difficulty, Babinet designed a compensator by means of which a desired path difference can be introduced. It consists of two wedge-shaped sections **A** and **B** of quartz. The optic axis is lengthwise in A and transverse in **B**. The outer faces of the compensator are parallel to the optic axis. Therefore, the ordinary and the extraordinary rays travel with different velocities along the same direction inside the compensator. Moreover, the extraordinary ray in **A** behaves as ordinary in **B** while the ordinary in **A** behaves as extraordinary in **B**. Suppose a plane polarized parallel beam of light is incident normally at the point **C** of the Babinet's compensator. The beam is split up into extraordinary and ordinary rays. The path difference introduced between them after they have travelled a distance **CD** in **A** is. In **B**, the path difference introduced by **B** is . The crystals **A** and **B** are mounted such that **A** is fixed and **B** can slide along the surface of **A** with the help of a rack and pinion arrangement. In this way **($t_1 - t_2$)** can be made to have any desired value.

Micrometer reading for central band	Rotation of screw to replace dark band by other x10-3	Least count of screws	Linear displacement of wedge 2□

Hence any path difference can be introduced with the help of the Babinet’s Compensator and it can be used for light of any wavelength

Table.1

Table.2

Linear displacement of wedge 2□□for 2□□shift	Linear displacement in the present case x	Value x	2□□□ x□□□□l/x

Table.3

Micrometer reading for central Disc without quarter wave plate	Micrometer reading for central dark fringe with quarter wave plate	Linear displacement

Result: The elliptically polarized light have been analyzed with the help of babinet compensator**.**