Instruction Manual

B.Tech Physics Laboratory

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Contents

A Note to Students

Introduction:

The objective of Lab Experiments along with the theory classes is to understand the basic concepts clearly. The experiments are designed to illustrate important phenomena indifferent areas of Physics and to expose you to different measuring instruments and techniques. The importance of labs can hardly be overemphasized as many eminent scientists have made important discoveries in homemade laboratories. In view of this, you are advised to conduct the experiments with interest and an aptitude of learning.

This manual will provide the basic theoretical backgrounds and detail procedures of various experiments that you will perform in the Physics laboratory. Before that, here are some specific instructions for you to follow while carrying out the experiments. It also outlines the approach that will be undertaken in conducting the lab. Please read carefully the followings.

Specific Instructions:

1. ***You are expected to complete one experiment in each class.*** Come to the laboratory with certain *initial preparation*. The initial preparation will involve a prior study of the basic theory of the experiment, the procedure to perform the experiment so as to have a rough idea of what to do. In addition, it will also involve a ***partial*** **preparation** of the **lab report (journal) in advance** as mentioned later in this section.
2. ***You must bring with you the following materials to the laboratory:*** This **instruction manual**, ***journal (lab report)***and graph sheets if necessary, pen, pencil, measuring scale, calculator and any other stationary items required.
3. ***The format of a lab report (journal) shall be as follows:***

(a) The first sheet (page) will contain your name, branch name and roll number, date and title of the experiment.

(b) Each experiment should contain the following in order. Experiment Number, aim of experiment, apparatus needed, a brief theory with working formulae, ***observation tables with units,*** figures or diagrams whenever necessary. Write procedure ***in brief***.

(c) **Experimental observations**: Data from experimental observations should be recorded in proper tabular format with well be documented headings for the columns. The data tables should be preceded by the least counts of the instruments used to take the data and numerical value of any constant, if any, used in the table.

(d) **Graphs:** (whenever applicable) Always label your graph properly. Be very clear to write the proper units, scale, experiment number, etc.

(e) **Relevant calculations**: Calculations should be done neatly and carefully in proper unit. Error analyses must to present your result.

(f) **Final results** along with error estimates.

(g) Remarks if any.

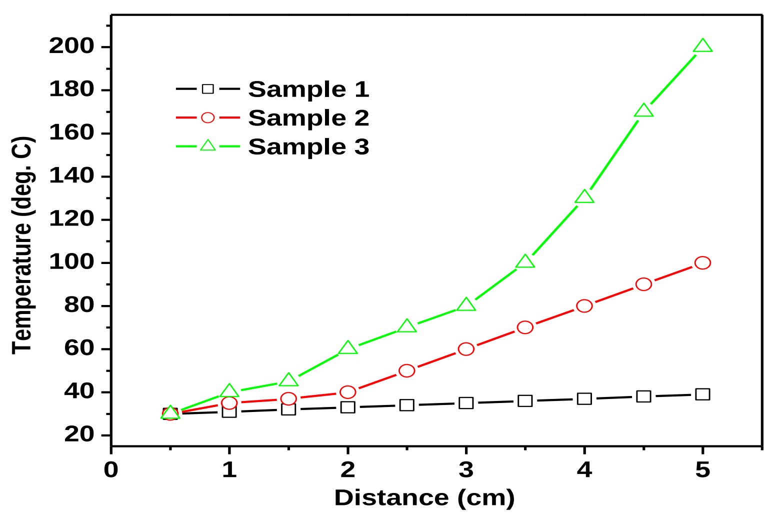
4. You must record your data directly in ***your lab record (Journal).*** Switch off any power supply etc. used and put back the components of the apparatus in their proper places. Complete the rest of the relevant calculations, error analysis, graphs (if necessary), results, and conclusion and ***obtain your grade*** of the performed experiment ***before leaving the laboratory*** from concerned Faculty (Instructor).
5. Last but not the least - *please handle the instruments with care and maintain utmost discipline and decorum of the laboratory*.
6. Be honest in recording your data. Never cook up the readings to get desired/ expected results. You never know that you might be heading towards an important discovery.

Graphs

A graph is simply a diagram illustrating the relationship between two quantities, one of which varies as the other is changed. The quantity that is changed is called “independent variable”, the other is called the “dependent variable”. The following general points should be noted:

1. Scale must not be too small – loss of accuracy, scale should not be too large – exaggeration of accidental errors. Scales on each axis are chosen usually the same unless one variable changes much more rapidly than the other, in which case it is plotted on a smaller scale.
2. The independent variable is placed / plotted horizontally and dependent variable placed / plotted vertically.
3. The origin need not represent the zero values of variables – unless definite reference to the origin is required.
4. Graph should be titled. It should have captions containing - a – standard name of variable – b – its symbol, if such a thing exists, and – c – standard abbreviation for the unit of measure.
5. Numerals representing scale values should be placed outside the axis. Values less than unity should be written as 0.47, not .47 . Use of too many ciphers should be avoided. Thus if scale numbers are 10,000; 20,000; 30,000 etc. They should be written as 1.0, 2.0, 3.0 with the caption – say pressure in 10^4 N/m^2. Similarly scale numbers 0.0001; 0.0002; 0.0003 etc. Should be written as 1.0, 2.0, 3.0 with the caption – say pressure in 10^{-4} N/m^2
6. All letterings should be easily readable from the bottom of the graph.

Example:



AN INTRODUCTION TO ERROR ANALYSIS

Suppose the length of an object is measured with a meter scale and the result is given as 11.3 cm. Does it mean that the length is exactly 11.3 cm? The chances are that the length is slightly more, or slightly less, than the recorded value but as the least count of the scale is one mm (it cannot read fraction of a mm) the observer rounds off the result to the nearer full mm. Thus, any length greater than 11.25 cm and less than 11.35 cm we can only conclude that the actual length is anywhere between 11.25 and 11.35 cm. The maximum uncertainty (on either side) or the maximum possible error, δ1, is 0.05 cm which is half the less count of the scale.

Let the object under consideration be a glass plate. To obtain the volume of the plate, suppose we measure the width 'b' with slide calipers and the thickness 't' with a screw gauge – whose least counts are respectively 0.1 mm and 0.01 mm. Let the result obtained, after averaging over many measurements, be

$$b = 2.75 \text{ cm}$$

$$t = 2.52 \text{ mm} = 0.252 \text{ cm}$$

and $$1 = 11.3 \text{ cm}$$

as measured by a meter scale with one end at zero exactly! We note that the coincidences noted in the vernier scale on the head scale of the screw gauge might not have been exact and represent only the nearest exact reading. Hence these measurements also include the corresponding uncertainties each equal to half the least count. So we have

$$1 = 11.3 \pm 0.05 \text{cm}$$

$$B = 2.75 \pm 0.005 \text{ cm}$$

$$t = 0.252 \pm 0.0005 \text{ cm}$$

Note that ± 0.05 cm, ± 0.005 cm, ± 0.0005 cm are actually instrumental errors. Personal errors – like reading 11.3 as 11.2 or 11.4 are not taken into account. To avoid personal errors average values of many readings has to be used. The volume calculated from the recorded values of 1, b and t is

$$V = (11.3 \times 2.75 \times 0.252) = 7.8309 \text{ cm}^3$$

Take care to avoid writing cm as mm, mm as cm etc. This is also personal error but a careless one at that.

However, since each observation is subject to an uncertainty, there should be an uncertainty in the result V too. How can the cumulative effect of the individual uncertainties on the final result be estimated?

Let the maximum error in V due to δ1, δb, and δt be δV. Then,

$$(V \pm \delta V) = (1 \pm \delta 1)(b \pm \delta b)(t \pm \delta t)$$

V + δV will corresponds to maximum positive values of δ1, δb, δt,

$$(V + \delta V) = (1 + \delta 1)(b + \delta b)(t + \delta t)$$

Or

$V(1 + \delta V/V) = 1bt\,(1+\delta 1/1)(1 + \delta b/b)(1 + \delta t/t)$

Cancelling V = 1bt from both sides and using the approximation

$$(1 + x)\,(1 + y)\,(1 + z) = 1 + x + y + z \text{ as } x<<1,\ y<<1,\ z<<1,$$

We obtain

$\delta V/V = \delta 1/1 + \delta b/b + \delta t/t$

The relative error in the product of a number of quantities is the sum of the relative errors of the individual quantities.

$\delta 1/1 = 0.05 / 11.3 = 0.0044$

$\delta b / b = 0.005 / 2.75 = 0.0018$

$\delta t / t = 0.0005 / 0.252 = 0.002$

$\delta V / V = 0.0082$

From the value V= 7.8309 , we have

$\delta V = 7.8309 \times 0.0082 = 0.064213 \text{ cm}^3$

(rounded off to one significant digit).

The result of the measurements is therefore

$$V = 7.8309 \pm 0.06 \text{ cm}^3$$

An important point to be noted is that writing the volume as 7.8309 cm3 would convey the idea that the result is measured accurate to 0.0001 cm3. We know from the calculated error that this is not the case and error is in the second decimal place itself. We are not certain that the second decimal is 3 but it may be 3 + 6. The volume may be anywhere in the range 7.77 to 7.89 cm3. As the second decimal place is subject to such an uncertainty, it is meaningless to specify the subsequent digits. This result should therefore be recorded only up to the second decimal place. [The error could be much larger if the least counts themselves are taken into account].

Thus $V = (7.83 \pm 0.06) \text{ cm}^3$

It is the calculation of the maximum error in the result, based on the least counts of the different instruments used that can indicate the number of significant digits to which the final result is accurate. Suppose we now measure the mass of a plate correct to a milligram and the result is

$$m = (18.34 \pm 0.005)\text{gm}$$

The density 'd' can be calculated from m and V.

$$d = m/v = 18.34/7.83 = 2.3423 \text{ gm cm}^{-3}$$

To estimate the uncertainty in d , we write

$(d + \delta d) = m + \delta m/ \nu - \delta \nu$

As the <u>maximum </u>density will correspond to the <u>greatest mass and least volume</u>.

$d(1 + \delta d/d) = \frac{m}{\nu} \frac{(1+\delta m/m)}{1-\frac{\delta \nu}{\nu}}$

$$1 + \delta d/d = \left(1 + \frac{\delta m}{m}\right) \left(1 - \frac{\delta \nu}{\nu}\right)^{-1}$$

As $\frac{\delta \nu}{\nu}$ and $\frac{\delta m}{m}$ are very much less than 1,

$\delta d/d = \frac{\delta m}{m} + \frac{\delta \nu}{\nu}$

The relative error in the quotient of two quantities is (also equal to the sum of the individual relative errors).

$$\frac{\delta m}{m} = \frac{0.005}{18.34} = 0.0003$$

$$\frac{\delta d}{d} = 0.0085$$

$\delta d = 0.0085 \times 2.3423 = 0.02$ gm/ cm^{-3}

Therefore d= (2.3423 ± 0.02) or (2. 34 ± 0.02) gm / cm^{-3}

[The error in measurements may be many times the least count if the instrument is not properly designed. Least count may often signify readability/ resolution and not the accuracy. Repeated measurements falling outside the least counts are indicative of this]

Other situations:

1. Suppose x is the difference of two quantities a and b, whose measurements have maximum possible errors as δa and δb. What is δx?
   X =a – b
   $(x \pm \delta x) = (a \pm \delta a) - (b \pm \delta b)$

The maximum value of the difference x corresponds to maximum a and minimum b

$$(x + \delta x) = (a + \delta a) - (b - \delta b)$$

$$= (a - b) + (\delta a + \delta b)$$

Cancelling x = a – b,

<u>$\delta x = \delta a + \delta b$</u>

In a sum or difference of two quantities, the uncertainty in the result is the sum of the actual uncertainties in the quantities – (Not the relative uncertainties).

2. If p $=\frac{xy^2}{ab}(1 + m), what\ is\ \frac{\delta p}{p}$?

First δ(1 + m) = δ1 + δm

Y^2 can be dealt with as a product of y and y.

$$\frac{\delta y^2}{y^2} = \frac{\delta y}{y} + \frac{\delta y}{y} = 2\frac{\delta y}{y}$$

$$\frac{\delta p}{p} = \frac{\delta x}{x} + \frac{\delta (y)^2}{y^2} + \frac{\delta a}{a} + \frac{\square b}{b} + \frac{\delta 1 + \delta \mathrm{m}}{(1+m)}$$

$$= \frac{\delta x}{x} + 2\frac{\delta y}{y} + \frac{\delta a}{a} + \frac{\delta b}{b} + \frac{\delta 1 + \delta \mathrm{m}}{(1+m)}$$

Questions:

1. Suppose x = (a+b)/ (c-d). To minimize the uncertainty in x, which of the four quantities must be measured to greatest accuracy, if all four quantities a, b, c, d are of the same order of magnitude?

2. The period of a simple pendulum is measured with a stop watch of accuracy 0.1 second. In one trial 4 oscillations are found to take 6.4 secs, in another 50 oscillations take 81 secs. In this relative uncertainty depends only on the least count of the instrument – in this case the stop watch? How can the relative uncertainty in the period be minimized?

3. The refractive index of a glass slab may be determined using a vernier microscope as follows. The microscope is focused on a marking on an object placed on a platform and the reading, a, on the vertical scale is noted. The glass slab is placed over the object. The object appears raised. The microscope is raised to get the image is focus and the position on the scale, b, is again noted. The last reading, c, is found raising the microscope to focus on a tiny marking on the top surface of the slab. The least count of the vernier scale is 0.01mm. The readings a, b, c are respectively 6.128 cm, 6.497 cm, and 6.128 cm. Calculate the refractive index and the percentage error in the result. Express the result to the accuracy possible in the experiment, along with the range of error.

Note:

In the above case cited we have used our judgment i.e. the ability to estimate the reading to ONE HALF the least count of the instrument. If we take that the actual error is ONE least count on either side of the measured quantity all the errors calculated in the above cases would be doubled.

References

1. Practical physics – by G.L.Squires, Cambridge University Press,4th edition, 2001.
2. A text book of Practical Physics by M.N. Srinivasan, S. Balasubramanian and R. Ranganathan, Sultan Chand and Sons, First edition, 1990.

Experiment-1

The radiation correction

Aim: To find the radiation correction in the final temperature Joule's experiment.

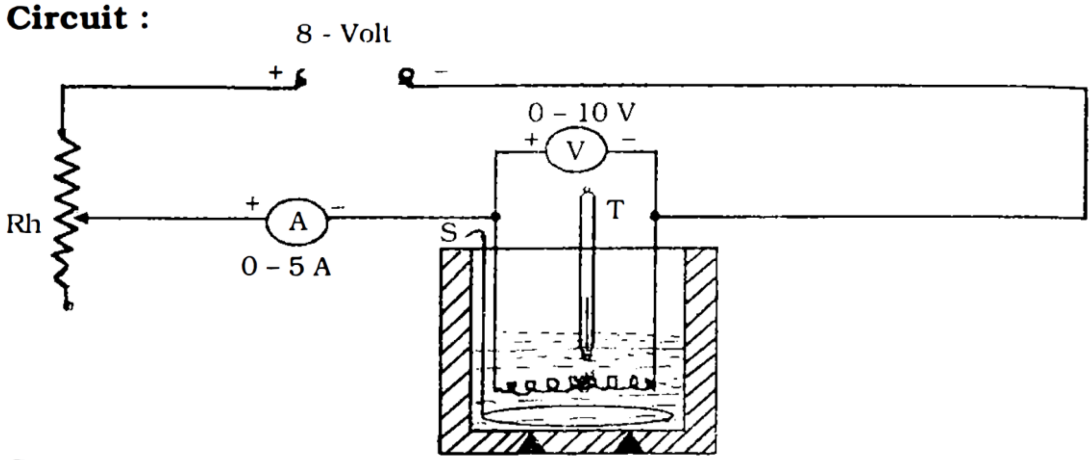
Apparatus: Joule's calorimeter, thermometer, Rheostat, voltmeter, ammeter, stop-clock etc.

Theory: When the water in the calorimeter is heated by passing electric current, loss of heat takes place due to radiation even the calorimeter is placed in the wooden insulating box. As a result the temperatures of water recorded by the thermometer are not true, and hence are to be corrected using an appropriate method. This correction is known as radiation correction. Correction in 'temperatures are done as per illustration given as under.

Time (minute)	Temp. (θ °C)	Mean Temp (θ_m °C)	$d\theta/dt$	Correction	Corrected temp.
0	30	-	-	-	30
1	31	30.5	$\delta1$	$\delta1$	$30+\delta1$
2	32	31.5	$\delta2$	$\delta1+\delta2$	$32+\delta1+\delta2$
3	33	32.5	$\delta3$	$\delta1 +\delta2+\delta3$	$33+\delta1+\delta2+\delta3$

Method: Connect the circuit as shown in the fig. Take adequate amount of water in the calorimeter. Record the initial temperature of water and ensure that initial temperature of water and room temperature are same. Pass 1·8 to 2·0 ampere current in the circuit. Record the temperature of water at the interval of one minute, till the final temperature of water is minimum 5°C higher than the initial temperature. Switch off the current and record the temperatures of the cooling water at the interval of two minutes till the fall in temperature is minimum l° C. Draw the cooling curve and find the average rate of cooling dS/dt at any mean temperature (Sm.) Take dS/dt equal to zero at room temperature. Using above two values of $d\theta/dt$ and corresponding temperatures. Prepare $d\theta/dt \rightarrow \theta_m$ graph. Use this graph to find the rate of cooling at different mean temperatures and apply corrections to the recorded temperatures and find the final corrected temperature.

Circuit :



Observation Table:

[1] Heating part observation:

Ob. No.	Time (minute)	Observation Temp. (θ) $^\circ C$	Avg. Temp.(θ_m) $^\circ C$	Correction $\delta\theta$ $^\circ C$	Total Correction $\sum\delta\theta$ $^\circ C$	Final θ $^\circ C$

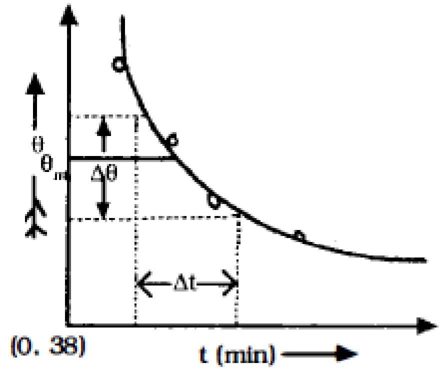
[2]Cooling part observation:

Ob. No.	Time (minute)	Temp. θ $^\circ C$

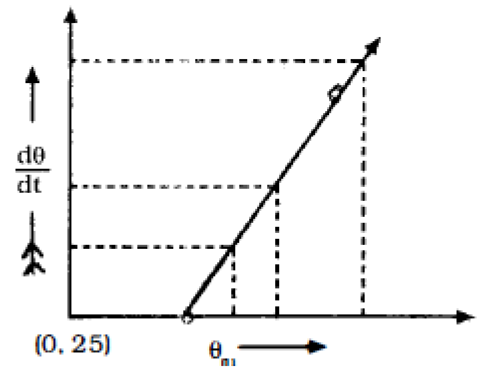
Table No. :-[3]

Avg. Temp. (θ $^\circ C$)		
$d\theta/dt$ $^\circ C/$		

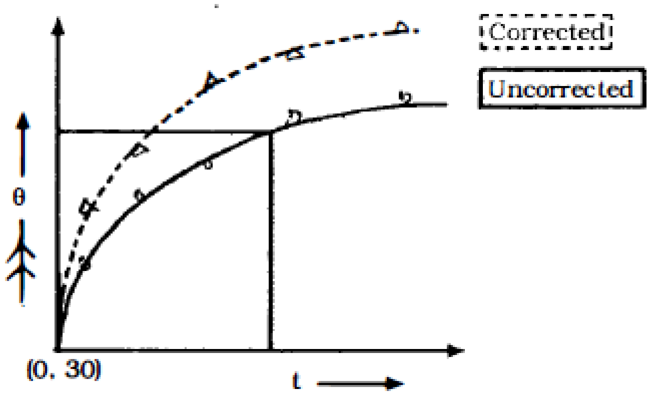
Graphs :



(1) Cooling graph [θ → t]



(2) $d\theta/dt \rightarrow \theta_m$



(3) Heating graph (θ → t)

$$\left(\frac{d\theta}{dt}\right)_{\theta_m} \cong \left(\frac{\Delta\theta}{\Delta t}\right)_{\theta_m} = \_\_\_\_\_\_\_\_ \ \theta^\circ\ C/min.$$

Result: The radiation correction in the temperatures of the system (calorimeter + water) is done by using an appropriate method. The graph of corrected temperatures → lime is plotted. The correction in final temperature (θ_f____ °C) comes out to be $\sum\delta n$ =_____°C

Experiment-2

Prism Angle

Aim: To measure the reflecting angle of prism using spectrometer by (i) keeping prism table fixed and rotating the telescope. (ii) Keeping the telescope locked and rotating the prism table.

Apparatus: Spectrometer, prism, Hg-source, magnifying lens, reading lamp.

Method:

Measurement of prism angle A by rotating telescope and keep fixing the prism table.

Adjust the spectrometer for parallel rays.

Mount the prism as shown in the fig.1 such that the apex coincide with the center of the prism table.

View the reflection of the slit on the left side of prism and bring it on the cross wire and remove the parallax. Note down the reading of both the windows as α and β.

Now rotate the telescope so that reflection of the slit from the right hand side face of the prism coincide with the telescope cross wire. Again Note down the reading of both the windows as α and β. Take the average and find **A**

Measurement of prism angle A by rotating prism table and fixing the telescope.

Mount the prism as before and take the reading on R.H.S reflection of any one windows say β.

Now fix the telescope and rotate the prism table in clock wise direction till the reflation of slit from the other side of the prism coincides with the telescope cross-wire. Note down the reading as β' (fig.2).

From the geometry of fig.2 it is apparent that

$\theta = |\beta - \beta'|$ and $\mathbf{A = 180} - \theta$

Diagram:

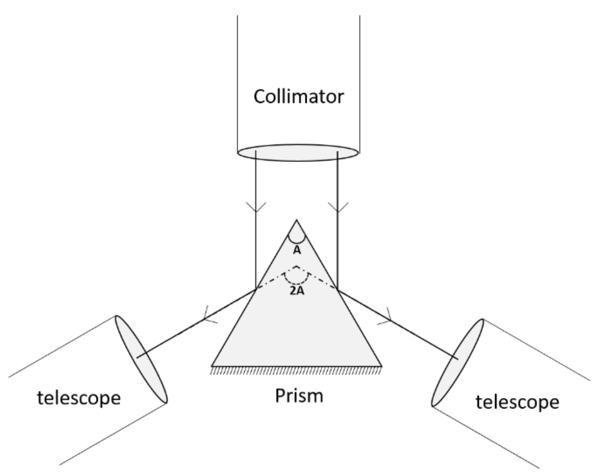


Figure.1

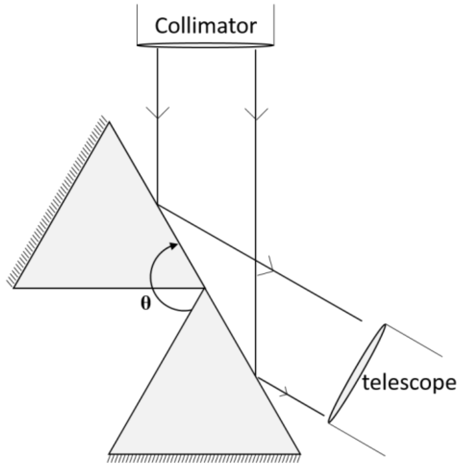


Figure.2

Observation Table. 1: Fixed the prism table

Reflecting Surface of Prism	Spectrometer Reading		Angle between reflected rays from left and right surface (2A°)	Mean 2A°	A°
	Window 1	Window 2			
Left surface	α =	β =	α ~ α =		
Right surface	α' =	β' =	β ~ β' =		

Observation Table. 2: Fixed the telescope

Reference: Right Reflecting (Fig.2)	Spectrometer Reading (note down any one windows reading)		Turning Angle θ°= β ~ β'	Prism Angle A° = 180°- θ
	Before rotation, β	After rotation, β'		

Calculations:

Result: The reflecting angle of prism, A=……°

Conclusion:

Experiment-3

Magnetic Field of Circular coil

Aim: To study the variation of magnetic field along the axis of a circular coil carrying steady current.

Apparatus: Circular coil, Battery, Rheostat, one-way key, Reversing key, Ammeter, Magnetic compass, Connection wires.

Formula: - $B_x = B_H \tan\theta$

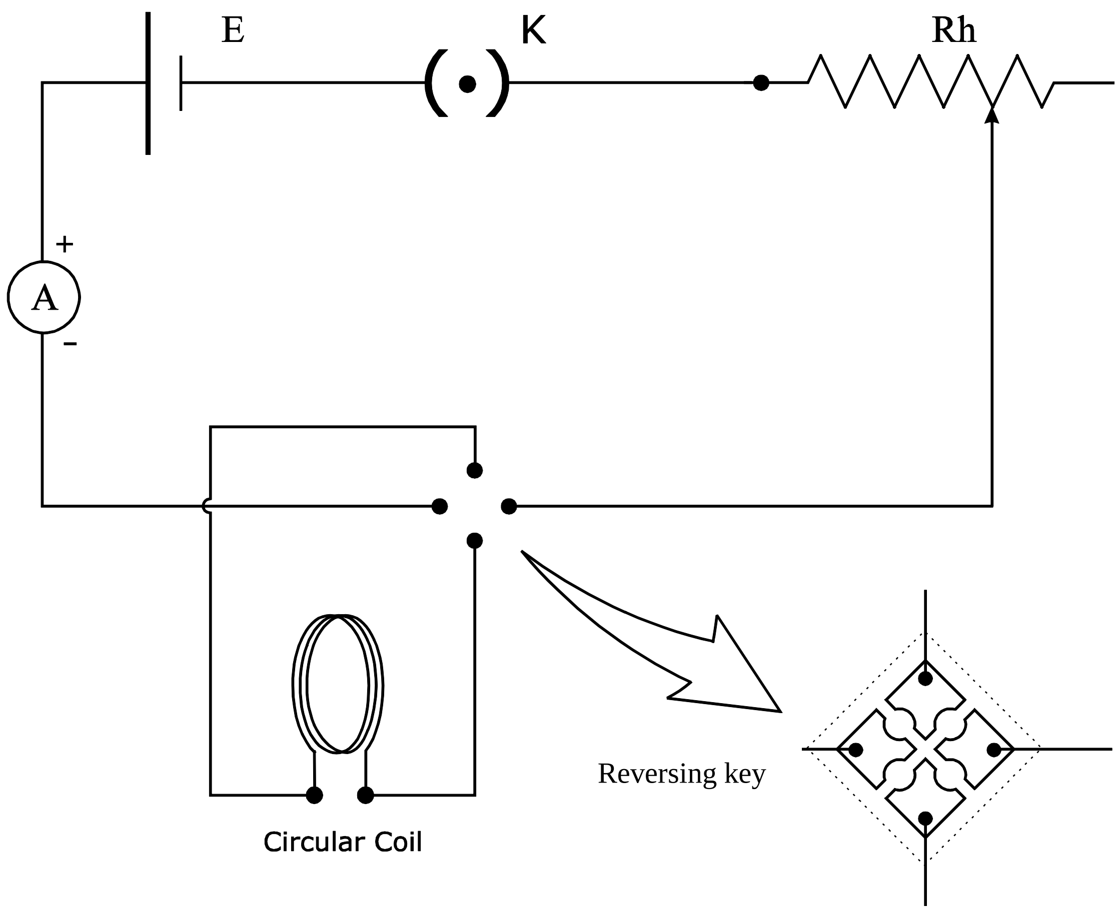
Where x = Distance between the center of the coil and the center of magnetic needle

B_X = Magnetic field due to the current carrying Circular coil at X.

B_H = Horizontal component of the earth's magnetic field (0.36×10^{-4} Weber/m^2)

θ= Deflection of the magnetic needle of the compass in degrees.

Circuit Diagram: -



Observation Table:

1) Constant Current (I) passing through the coil = ________ mA

Obs. No.	X m	Deflection (in degrees)				Mean θ	tanθ	B_X (10^{-5} Wb/m^2)
		θ_1	θ_2	θ_3	θ_4			
Centre	0							
LHS 1								
2								
3								
4								
5								
6								
7								
RHS 1								
2								
3								
4								
5								
6								
7								

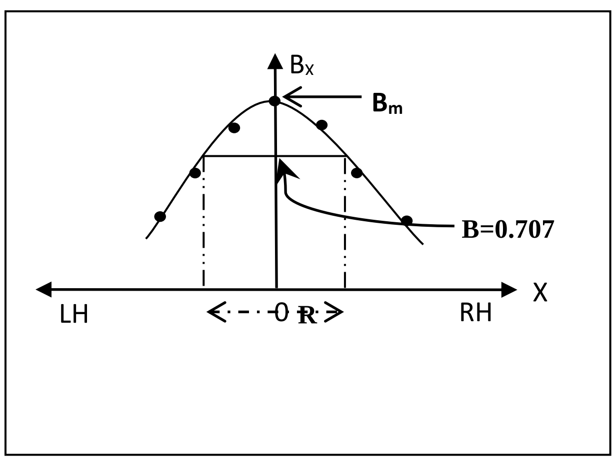
2). At centre of coil;

Obs. No.	I (mA)	Deflection (in degrees)				Mean θ	tanθ	B_X (10^{-5} Wb/m^2)
		θ_1	θ_2	θ_3	θ_4			
1								
2								
3								
4								
5								
6								
7								

Graphs:

1. Plot graph between magnetic field vs position

2. Plot graph between magnetic field vs current



Result: Radius of circular coil,

R =………………….cm

Conclusion:

Experiment-4

Polarization of light: Malus' Law

Aim: To study the polarization of light, to verify Malus law and to find the Brewster angle for glass.

Apparatus: Laser source, polarizer, analyzer, photodiode, battery, multimeter, glass slab, optical table and stand.

Basic Theory: There are a number of ways an unpolarised light can be converted into a plane polarized light. You are given two polarizing sheets (polaroids). The light passing out of a polarizer is linearly polarized with the electric field E fixed in one direction in space as determined by the orientation of the polarizing sheet. If this light passes through a second polarizer (analyzer), then the light output depends on the relative orientation of the two polarizers. If the pass plane of the second polarizer is making an angle θ with respect to the electric field E, then the magnitude of the field in the output wave is cosθ and the output intensity is proportional to $\cos^2\theta$ thus the output intensity I of the light transmitted by the analyzer is given by

$$I = I_0 cos^2\theta \dots \dots \dots \dots \dots (1)$$

Where I_0 is the intensity of the polarized light on analyzer. This is known as Malus law.

Alternatively one can obtain polarized light by using a beam that is reflected at an interface at a particular angle called Brewster angle. Consider a polarized beam falling on an interface YZ (fig. 1). The beam is in XY plane and the polarization of the light is in the plane of incidence (electric field *E*I is in XY plane).

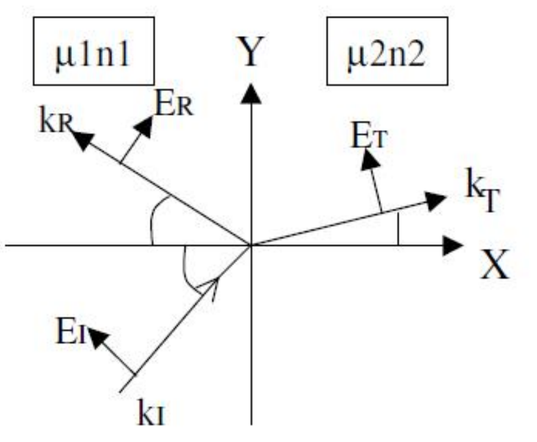


Fig. 1

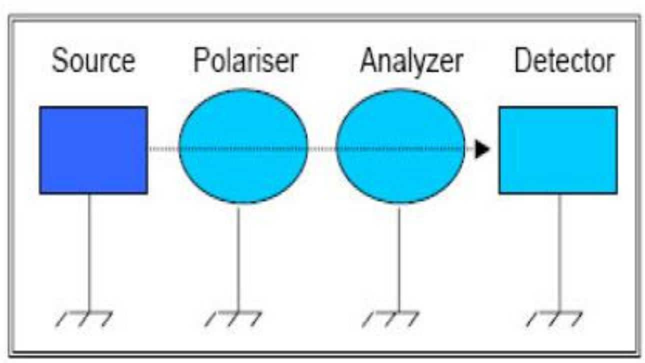


Fig. 2

The magnitude of the reflected electric field is given by

$$E_R = \left(\frac{\alpha - \beta}{\alpha + \beta}\right) E_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . . (2)$$

Where $\alpha = \frac{\cos\theta_T}{\cos\theta_I}$ and $\beta = \frac{\mu_1 n_1}{\mu_2 n_2}$. μ is the magnetic permeability of the material and n is the refractive index of the material.

Thus the reflectivity (E_R /E_I) depends on angle of incidence for the inplane polarisiation and goes to zero at a certain angle of incidence called Brewster angle □B given by $\tan\theta_B = \frac{n_1}{n_2}$. This fact can be used to get a polarised beam from an unpolarised beam. An unpolarised beam is made to incident at an interface at Brewster angle. The reflected beam will contain the perpendicular component only.

Experimental Setup

The set-up consists of a laser light source (partially polarised), polariser, analyser, and a photodiode (Fig. 2). The analyser unit is fitted with a circular scale to record the angular readings. Photodiode is used to measure the intensity of light. All the components can be mounted on an optical bench for proper alignment

Fig. 3: Experimental set-up: Malus' law.

Procedure

Set-up and procedure:

1. The experiment is set up according to Fig. 1. It must be made sure that the photocell is totally illuminated when the polarization filter is set up.

2. If the experiment is carried out in a non-darkened room, the disturbing background current i0 must be determined with the laser switched off and this must be taken into account during evaluation.

3. The laser should be allowed to warm up for about 30 minutes to prevent disturbing intensity fluctuations.

4. The polarization filter is then rotated in steps of 5° between the filter positions +/- 90° and the corresponding photo cell current (most sensitive direct current range of the digital multimeter) is determined.

Observation:

1. The experiment is set up according to Fig. 1. It must be made sure that the photocell is totally illuminated.

2. Using a digital multimeter the disturbing background current i0 must be determined with the laser switched off. This must be taken into account during evaluation.

3. Switch ON the laser. It should be allowed to warm up for about 30 minutes to prevent disturbing intensity fluctuations.

4. The polarization filter is then rotated in steps of 5° between the filter positions +/- 90° and the corresponding photo cell current (most sensitive direct current range of the digital multimeter) is determined.

5. Make the table required for angle and the corrected photo current. Identify the intensity peak and show that the polarization plane of the emitted laser beam has already been rotated by this angle against the vertical. It may look like Fig. 3 below.

6. Show that the corrected and normalized photo cell current as a function of the angular position of the analyser. It may look like Fig. 4 below. Malus's law is verified from the slope of the line.

Observation Table:

No	**Angle (Degree)**	**Current (I_T) μA**
1		
2		
3		
4		
5		
…		
…		

Results and Discussion:

1. Estimate the experimental errors.
2. Explain different light phenomenon happening duri

Experiment-5

Stefan's Law

Aim: To verify Stefan's fourth power law of cavity radiation.
Apparatus: Battery eliminator, 6 watt bulb, mill-ammeter, voltmeter, etc.
Theory : The radiation of the cavity radiator is directly proportional to the fourth power of absolute temperature of the black body i. e.

$$R = \sigma T^4$$

Where, R = Cavity radiancy
σ= Stefan's constant
T= Temperature of the radiator

The radiancy is directly proportional to the power radiated by the bulb.

$$R \propto T^4$$

Using (1) and (2) we can have

$$W_R \propto T^4$$

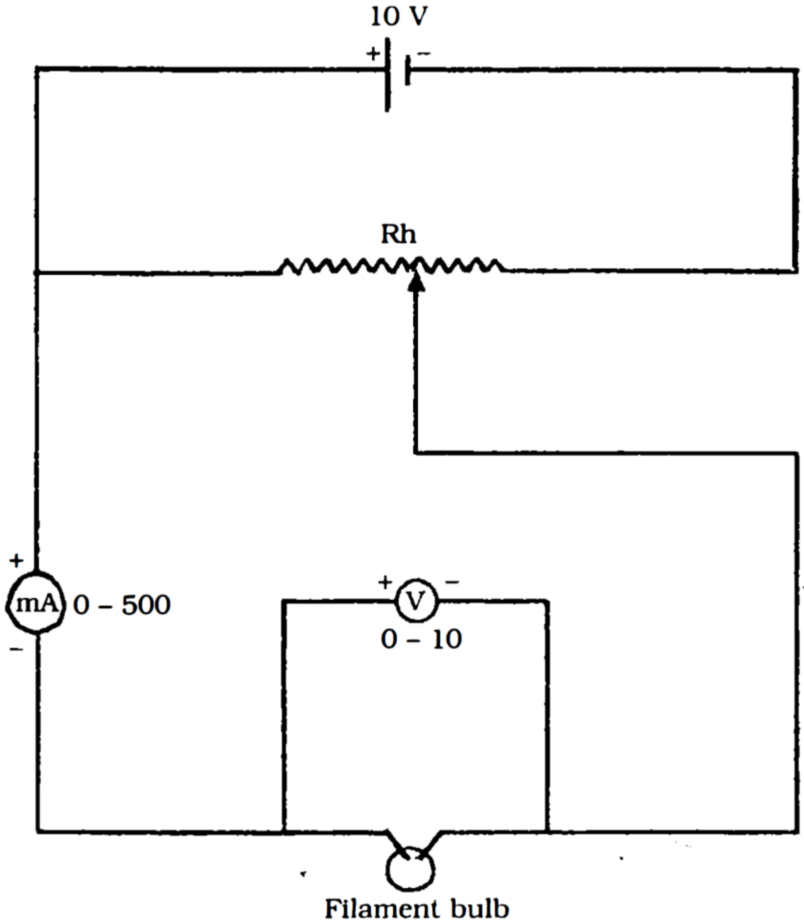
$$lnW_R = 4lnT + const.$$

The graph $lnW_R \rightarrow \; lnT$ is a straight line whose slope is four (4) which proves the Stefan's Fourth Power Law of cavity radiator.

Method:

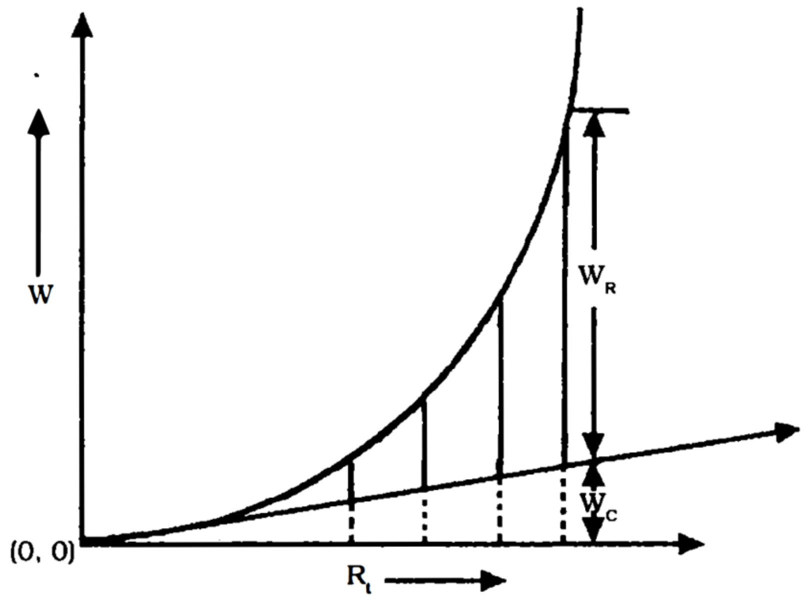
1. Connect the circuit as shown in the fig.
2. Pass the current through the filament (I_f) of the bulb and measure corresponding P. D. across filament. Start with some low value of current. (It is not necessary that in beginning bulb should glow)
3. Take eight different values of the filament current (I_f) in equal steps and record corresponding filament voltage (V_f).
4. Find the resistance of the filament of the bulb for all values of currents using Ohm's Law.
5. Calculate the Power consumed by the filament of the bulb using $W = V_f I_f$
6. Determine temperature of the filament by $R_t = R_0(1+\alpha t)$
   Where. R_t = Resistance as per step (4) and α = T.C.R of the filament
7. Plot $W \rightarrow \; R_t$ graph and determine (W_R) power lost by radiation by eliminating (W_c) Power lost by conduction for known values of Rt.
8. Plot $W_R \rightarrow \; lnT$ graph.
9. Find the value of the slope of the graph.

Circuit:

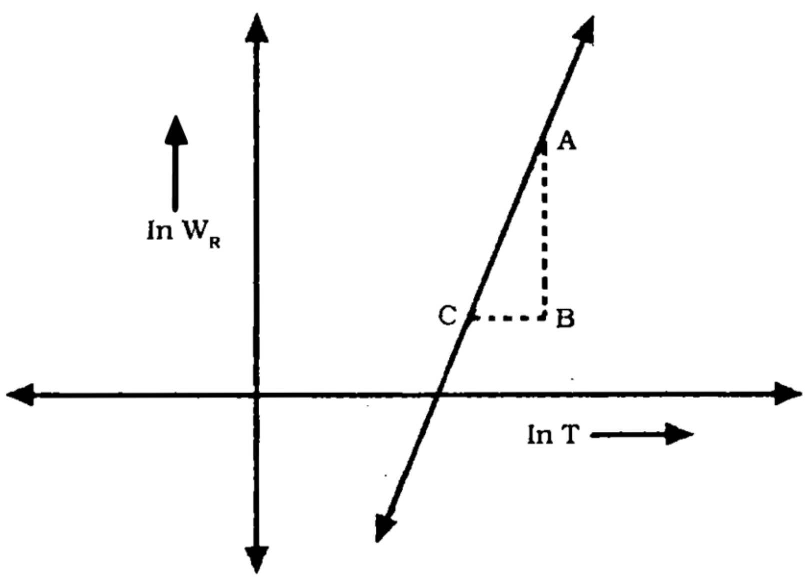


No.	Filament Current I_f (A)	P. D. across Filament V_f (V)	Power Consumed $W = V_f I_f$	Resistance of the Filament R_t	Temp. T	Power Lost W_R	ln W_R	ln T
1								
2								
3								
4								
5								

Graphs:



(2)



$$\text{Slope} = \frac{AB}{BC}$$

Result: The graph $W_R \rightarrow lnT$ is straight line. The slope of the line comes out to be 4 which is the power of the law $R = \sigma T^4$ and hence the law is verified.

Experiment-6

Plank’s Constant

Aim: To determine Planck's constant "h" using Photovoltaic cell.

Apparatus: Battery Eliminator, 6 Watts Lamp, Photovoltaic Cell, Rheostate, meter. Voltmeter. Microammeter.

Theory: The Planck's Law of black body (cavity radiator) radiation is given by;

$$R_\lambda = \frac{C_1}{\lambda^5}\frac{1}{\left[e^{\left(\frac{C_2}{\lambda T}\right)} - 1\right]}$$

Where, $C_1 = Constant,$

$C_2 = \frac{hc}{k_B} = Constant$

$h = Plank's\ constant$

$c = Speed\ of\ light$

$\lambda = Wavelength\ of\ Radiation$

For short wavelength and/or Low temperature equation (1) can be expressed as

$$R_\lambda = \frac{C_1}{\lambda^5}\frac{1}{e^{hc/\lambda kt}}$$

In the actual experiment the intensity of the bulb is recorded in terms of photocurent (Ip).

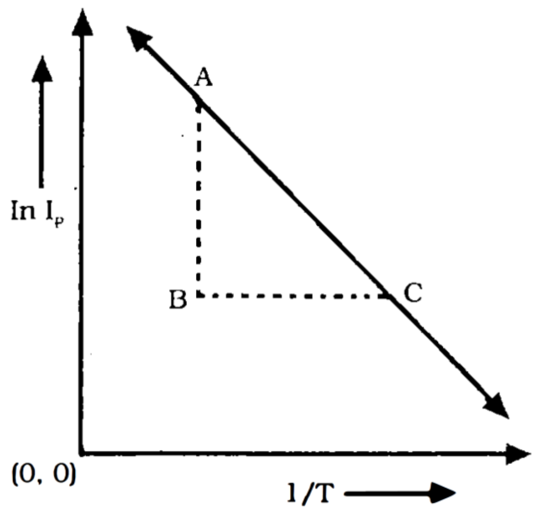
It is clear that.

$$I_p \propto \frac{1}{e^{hc/\lambda kt}}$$

$$lnI_p = Const. - \frac{hc}{\lambda k}\frac{1}{T}$$

The graph $lnI_p \rightarrow\ 1/T$ is a straight line. (According to equation (4)).

Graph :



$$\text{Slope} = \frac{hc}{\lambda k} = \frac{AB}{BC}$$

$$h = \frac{\text{Slope} \times \lambda \times k}{c} \quad \text{... (5)}$$

Where, $\lambda = 6{\cdot}60 \times 10^{-7}$ m
$k = 1{\cdot}38 \times 10^{-23}$ J/molecule °K
$c = 3{\cdot}00 \times 10^{8}$ m/s

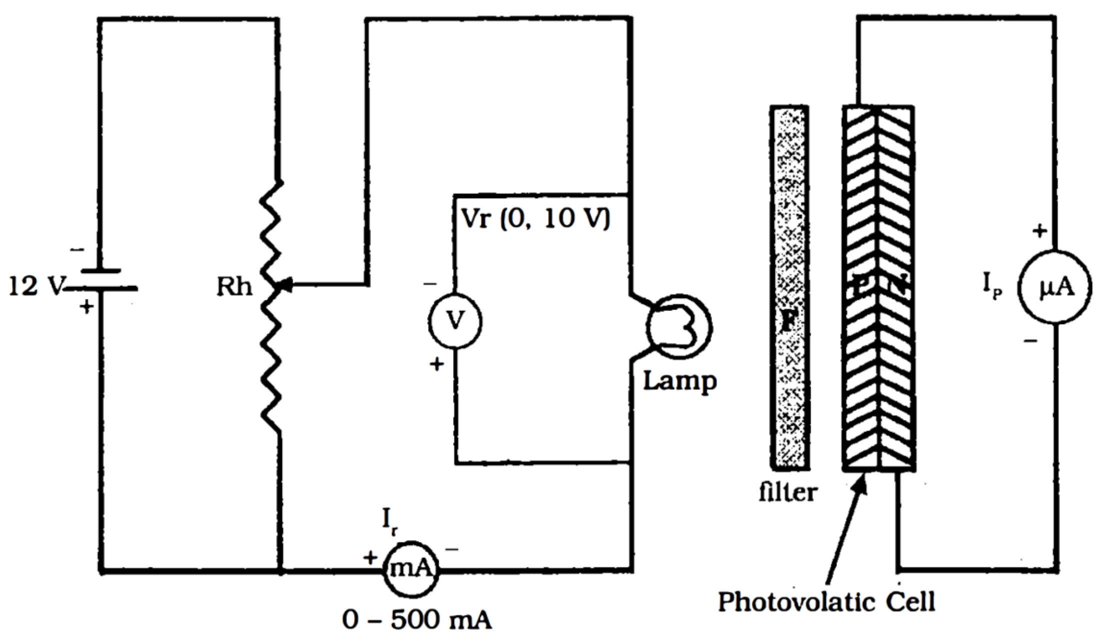
Method:

1. Connect the circuit as shown in the figure.
2. Pass the current through the filament of the bulb so that bulb glow become white. (In this situation filament of the bulb can be treated as black body radiator.)
3. Allow to fall the black body radiation on photovoltaic cell after proper filtering as shown in the figure.
4. Record filament current (I_f) filament voltage (V_f) and photo current (I_p) (Filament current (I_f) should be approximately more than 300 rnA.)
5. Repeat the experiment for different value of filament current (I_f) and measure corresponding value of filament voltage (V_f) and photocurrent (I_p)
6. Determine R_t (resistance of the filament of the bulb) using Ohm's law.
7. Determine the temperature of the filament using $R_t = R_0(1+\alpha t)$ relation.
   Where. R_t = Resistance of the filament at t° C
   R_o = Resistance of the filament at 0° C
   α = Temperature Coefficient of the resistance of the material of the filament
8. Plot the graph $lnI_p \rightarrow 1/T$ and obtain slope of the line anc;l find h using equation (5).

Table :

No.	filament current I_f (A)	P.D. across filament V_f volt	Photo current IP (μA)	Resistance of the filament $R_t = V_f/I_f$	Temp. of the filament T	ln I_p	$\frac{1}{T}$
1.							
2.							
3.							
4.							
5.							

Circuit :



Result : The value of the planck's constant as determined by a photovoltaic cell = ____________ J.S.

Experiment-7
Diffraction Grating

Aim: To determine the wavelength of the given sodium light source using plane transmission grating.
Apparatus: Sodium light source, Spectrometer, Plane Transmission Grating, Spirit-level, Magnifying glass, etc.

Formula : $(e + d)\sin\theta = n\lambda$

Where (e + d) = grating element = 2.54 cm/N

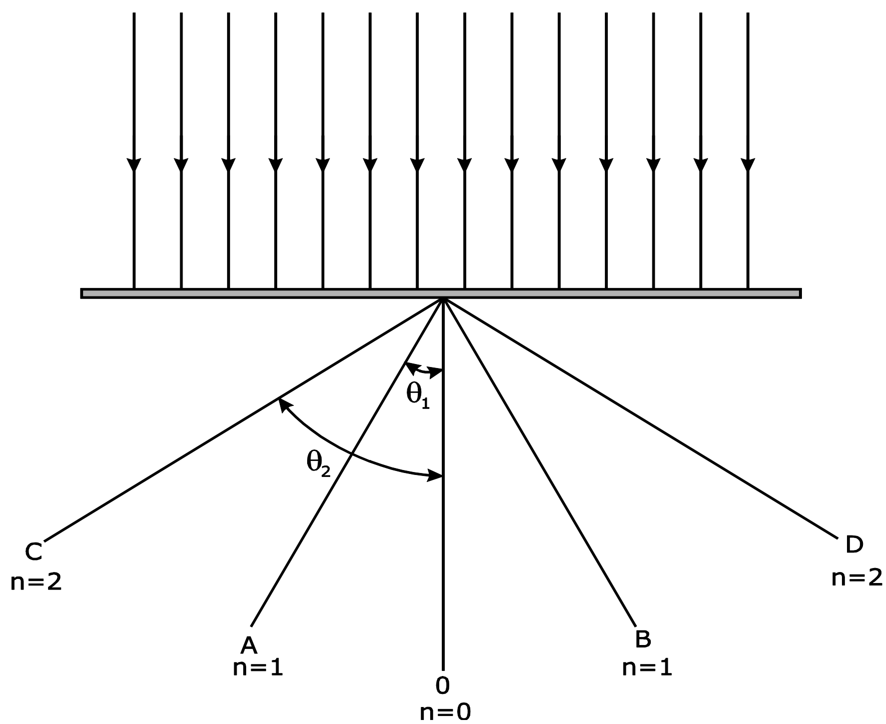
N= No. of lines per inch in the grating

θ = angle of diffraction

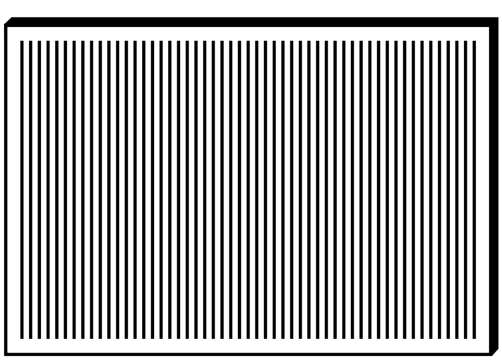
n = order of the spectrum

λ = wavelength of given light source

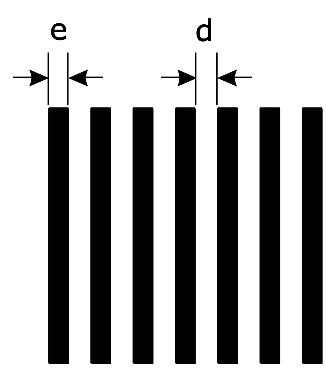
Diagram :



Simplified view of grating



Grating element (e + d)



Observation Table:

Least Count of Spectrometer: ______

Order of spectrum n	Position of Telescope	Spectrometer Readings		$2\theta_1$ = A ~ B	$2\theta_2$ = C~D
		Window 1	Window 2		
1st	A: LHS				
	B: RHS				
2nd	C: LHS				
	D:RHS				

Mean: $2\theta_1$ = _________ $2\theta_2$ = _________

θ_1 = _________ θ_2 = _________

Note: To eliminate Backlash error, take your observations in the following order: CABD or DBAC

Calculation: (1) For the first order of spectrum (n = 1):

$$\lambda_1 = \frac{(e+d)\sin\theta_1}{1} \text{ Å}$$

(2) For the second order of spectrum (n = 2):

$$\lambda_2 = \frac{(e+d)\sin\theta_2}{2} \text{ Å}$$

(3) Mean wavelength of the given sodium light source

$\lambda = (\lambda_1 + \lambda_2)/2$ Å

Result: The wavelength of the given sodium light source λ =___________Å

Experiment-8

Newton's Ring

Aim: To determine the radius of curvature of a given plano-convex lens using a source of known wavelength and the phenomenon of interference of light viz. Newton's rings.

Apparatus: Traveling microscope, Plano-convex lens, glass plates, sodium light source, etc.

Formula: $R = \frac{D_m^2 - D_n^2}{4\lambda(m-n)}$

Where, R $\rightarrow$ Radius of curvature of given plano-convex lens.

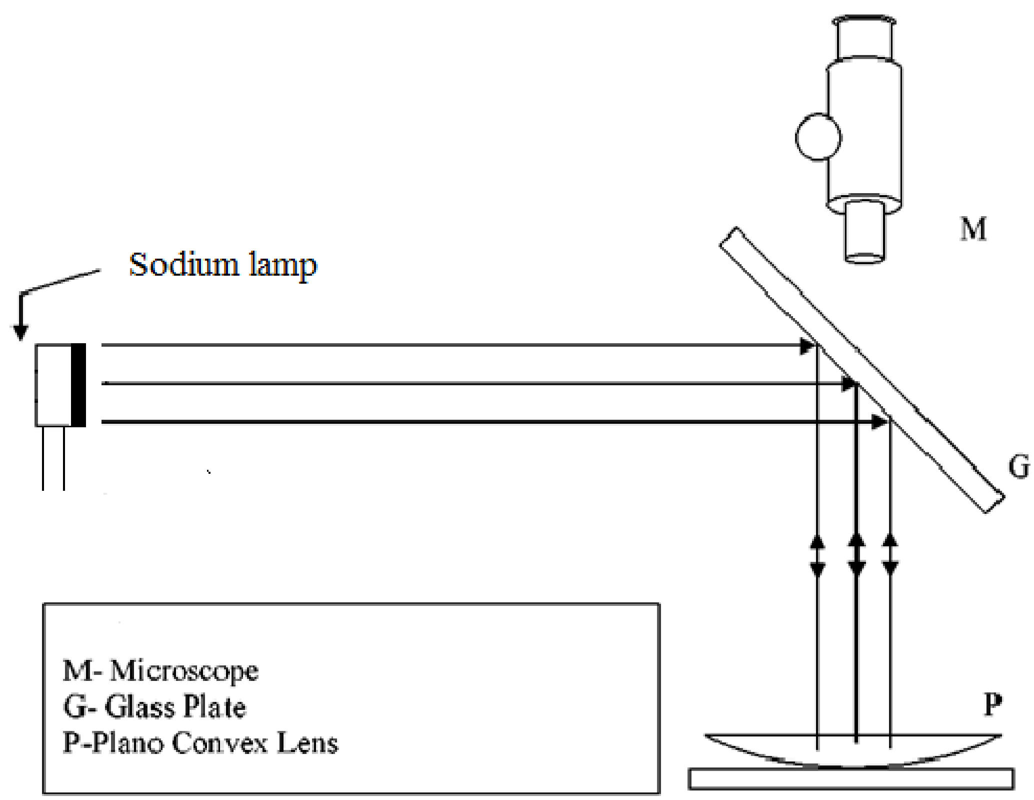
$D_m \rightarrow$ Diameter of the m^{th} ring

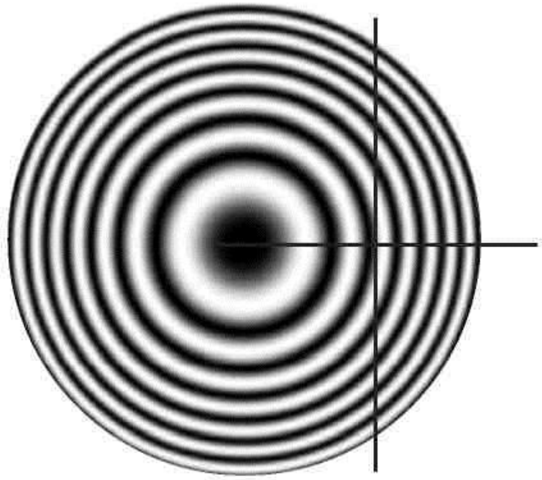
$D_n \rightarrow$ Diameter of n^{th} ring

m, n, $\rightarrow$ number of the ring as measured from center of the ring

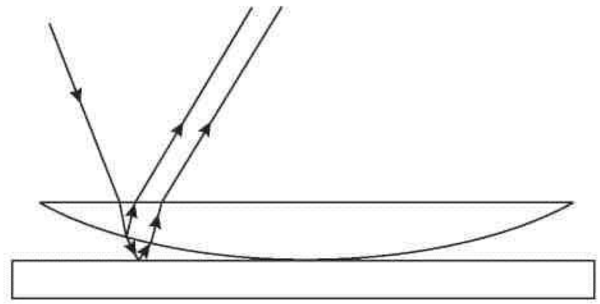
$\lambda \rightarrow$ Wavelength of the light source

Diagram:





Newton's Rings



Division of amplitude

PROCEDURE:

- Please ensure that all the glass plates and lenses are clean.
- Familiarize yourself with the Traveling Microscope (TM); in particular, with the fine and coarse motion of the TM.
- Recall how to read the scales on the TM: identify the Main Scale and the Vernier Scale. Find the Least Count of the TM and make sure that you know how to read the scale (see below).
- Align the source of light of the given wavelength such that the light is incident at the center of the inclined glass plate as shown in the diagram. (Note: The success of optic experiments depends largely on good alignment.).
- Focusing of the TM: First of all, move the eyepiece back and forth until the cross-wires are distinctly observed. Now take a small piece of paper and mark on it a 'cross' and put it on the top of the horizontal glass plate. Focus the TM on the marked 'cross'. Do not disturb this focusing arrangement throughout the experiment. Do not forget to remove the paper after focusing is done.
- Identify the flat and the curved surfaces of the plano-convex lens. Take the plano-convex lens and place it on the horizontal glass plate as shown in the diagram.
- If your adjustments are OK then you should be able to see the Newton's Rings. If not, then go back and repeat the previous steps carefully.
- Once the rings are obtained ensure that the center of the pattern of the rings and the intersection of the cross-wires coincide. The horizontal cross-wire should be along the diameter of the rings.
- Count the rings from the center, which is taken as the zeroth ring, and go to the left-hand side until you reach the 18th ring. Arrange the transverse cross-wire along the tangent line to the bright/dark 18th ring. Note the readings on the horizontal scale of the TM. Take the readings for the other numbered rings as mentioned in the observation table below. In particular, move the TM in one direction only (say, left to right) while taking the readings. This will prevent errors due to what is known as the "back-lash" error. Using the value of the wavelength, find the radius of curvature of the given plano-convex lens.
- Now without disturbing the TM (in particular, do **NOT** change the lens) replace the source with the source of unknown wavelength. Repeat the procedure as in the last step. Enter your observations in a new observation table.
- Find the wavelength of the second source and hence find the energy band gap for the LED source.

Observations:

Smallest division on the main scale (SDMS)= …….;

Total Number of Divisions on the Vernier Scale (TNDVS) = _______ ;

Least count= SDMS/TNDVS= ……

Observation Table:

1) Least count of the traveling microscope = ------------- cm
2) Wavelength of the light source λ = ------------- nm

Obs. No.	Number of Ring	Microscope Readings		Diameter of Ring D (LHS~RHS)	D^2 [cm^2]
		LHS [cm]	RHS [cm]		
1	18				
2	16				
3	14				
4	12				
5	10				
6	8				
7	6				
8	4				

Note: You need to make another table for another source.

Graph 1 (No. of rings vs diameter square) for the known wavelength source

Slope = AB/BC

R = slope/ 4λ