DEPARTMENT OF PHYSICS

INDIAN INSTITUTE OF TECHNOLOGY HYDERABAD

B.Tech. Laboratory Manual

Course Code - EP 1031

(For internal circulation only)

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

SAFETY INSTRUCTIONS FOR PHYSICS LABORATORY

The following guidelines have been established to minimize or eliminate hazards in the laboratory.These guidelines have also been provided to maintain a safe laboratory environment. It is the responsibility of each person that enters into the laboratory to understand the safety and health hazards associated with potential hazardous materials and equipment in the laboratory. It is also the individual's responsibility to practice the following general safety guidelines at all times:

Note that it is better to NOT proceed if you suspect a safety issue than to learn the hard way!

General safety instructions:

1. Wear shoes that will protect your feet from electric shock.
2. Keep work areas and apparatus clean, rearrange apparatus in an orderly manner, and report any damaged or missing items.
3. Do not look at LASER light directly as it may cause permanent eye damage.
4. Never leave lasers, power supplies or other electrical equipment unattended. Always turn these items off when not in use.
5. Observe the warning signs sticker on the wall or pasted on the instruments.
6. Do not modify or damage the laboratory equipment in any way unless the modification is directed by the instructor. This does not include the changing of a lab setup as prescribed by the procedures in the carrying out of measurements.
7. Do not leave your experimental equipment unattended while it is in operation. Do not fiddle around with apparatus. Handle instruments with care.
8. Never work in the lab unless an instructor is present and aware of the experiment, you are doing.
9. Report any accident or injury to the instructor immediately, no matter how trivial it may appear.
10. Return all materials and apparatus to the places designated by your Instructor. Follow your instructor directions for disposal of any waste materials.
11. Know the locations of the exits (of the room and the building). Know the location of the fire extinguishers. If a fire occurs,your job is to leave the lab immediately after informing to instructor with your lab partners.
12. Eating, drinking, smoking, gum chewing, and taking medicine in laboratory is strictly prohibited.
13. Do not do any experiment if you are ill or not feeling well.
14. Clean the work area after the completion of experiment and at the end of the day.

Glassware safety:

1. If a thermometer breaks, inform your instructor immediately. Do not touch either the mercury or the glass with your bare skin.
2. Do not heat glassware that is broken, chipped, or cracked. Use tongs or a hot mitt to handle heated glassware. Allow all equipment to cool before storing it.
3. If a bulb breaks, notify your instructor immediately. Do not remove broken bulbs from sockets.

Electrical safety:

1. Never switch on your circuit until it has been checked by your Instructor. Never rewire or adjust any element of a closed circuit.
2. Never work with electricity near water. Be sure that the floor and all work surfaces are dry.
3. Do not work with any batteries, electrical devices, or magnets other than those provided by your instructor.
4. When you have finished your work, check that the electric circuits are disconnected.

Clothing protection:

1. Tie back long hair, secure loose clothing, and remove loose jewellery to prevent their getting caught in moving or rotating parts in the equipments.

COORDINATORS

GENERAL INSTRUCTIONS

A suitable scheme for recording is as follows:

- **Title:** Write the title of the experiment with date in the margin of first page.
- **Aim:** Objective of the experiments.
- **Apparatus:** Write the required items to perform the experiment.
- **Circuit diagram:** Sketch the circuit diagram wherever it is necessary.
- **Method for recording:** Give full details of each measurement in the order in which they are done.
- **Measurements:** Record all measurements in tabular format, give the units of each measurement
- **Formulae:** Write down the formulae to be used in calculation or drawing graphs.
- **Calculation:** Show the calculations step by step. Convert all measured values into S.I. units and substitute them in the formulae used.
- **Graph:** If a graph is plotted, choose scales to use as much as possible the entire graph paper. Label the two axes and give the units. Mark the points plotted with crosses X or dots and mark circles. Use a sharp pencil to plot a graph.
- **Error analysis:** Estimate the possible errors.
- **Results & Discussion:** Write the result to a sensible order of accuracy. It must consist with the units.

EXAMPLE FOR THE TABLE OF MEASUREMENTS

A symbol for a quantity contains a numerical value and a unit. Thus Mass M = 0.02 kg. Consequently in the tabular format as follows.
For example,

Mass (M/kg)	Time (t/s)	Temperature(T/K or T/°C)	Length(l/m)

Plotting the graph:
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 others 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.

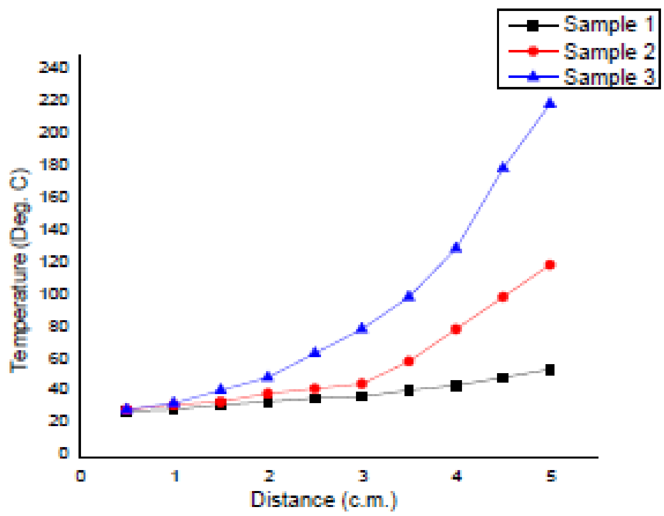
2. The independent variable is placed / plotted horizontally and dependent variable placed / plotted vertically.

3. The origin need not represent the zero values of variables – unless definite reference to the origin is required.

4. The graph should have title. It should have captions containing – a – standard name of variable – b-its symbol, if such a thing exist, and – c- standard abbreviation for the bit 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, and 3.0 with the caption – say pressure in 10^{-4} N/m^2. All letterings should be easily legible from the bottom of graph.

Example:



ABOUT THE CYCLE OF EXPERIMENTS

1. All the ten experiments should be completed during the semester.
2. One experiment has to be completed within one practical class.
3. The manual is for reading and planning the experiment in advance.
4. ALL READINGS TAKEN MUST BE DIRECTLY ENTERED IN THE RECORD BOOK. Each student can plan his/her own way of presenting the data. One can also think of graphical presentation wherever possible.
5. Every student must bring a CALCULATOR to the laboratory class and take it back when leaving laboratory.
6. Calculations should be completed, and the record has to be shown to the teaching assistant (TA) for evaluation on the same day.
7. Consider all possible errors carefully. Estimate the possible errors and also the overall errors in the results.
8. Each experiment has a number and this number has to be entered along with the title in the record book.
9. Each student is expected to write down his/her own conclusions about the results.

STUDENTS ARE NOT PERMITTED TO TAKE THE RECORD BOOK OUT OF THE LABORATORY BEFORE ALL THE EXPERIMENTS ARE DONE AND EVALUATED.

COORDINATORS
&
LABORATORY STAFF

AN INTRODUCTION TO ERROR ANALYSIS

Errors of observations:

The main objective of an experiment in Physics is to determine the numerical value of the required physical quantity. This is normally done by measuring several other quantities which are related to former by mathematical expression. The measurements in a laboratory often reduce to the reading of a scale or observing the coincidence between two marks. Such measurements involve 'errors'. i.e., observed value deviates from the true value. Errors of observations may be random and systematic.

Random errors:

The errors occurring from small fluctuations in experimental conditions and the personal adjustment of observer are called random errors.

Suppose that the value of the quantity to be measured depends on experimental conditions like temperature, humidity,etc. If,the temperature fluctuates slightly about the desired value during experiment, the measured value of the quantity will have an error due to varying experimental conditions. The error in this case is an example of a random error. An error may be positive or negative according to the measured value being higher or lower than the true value.

Systematic errors:

While taking the readings, if something occurs constantly or systematically to make the measured values always larger than the true value, the error it introduces is known as systematic error. Systematic errors may be divided into three categories:

Personal error:

The observer may have personal peculiarities; for instance, the person may have always the tendency to read too high or too low. The person may also not be physically fit and may suffer from eye-strain, fatigue etc. It may also occur that the person cannot avoid parallax. All these factors lead to personal errors.

Instrumental error:

The 'zero error' of measuring instrument, such as Screw gauge, Vernier calipers etc. are examples of instrumental errors.

External error:

External errors arise from external conditions, such as temperature, humidity, wind, vibrations etc. Assume that during an experiment, the temperature always remains high and a meter scale is used to measure a length, then the readings will have systematic error since the scale expands at high temperature and appropriate temperature corrections, humidity corrections, etc. are employed. Personal errors may be minimized if the experiment is performed several times and a mean of the results is taken. In some cases, the source of a systematic error is not definitely known but its occurrence is suspected. In such cases, the experiments are repeated under suitably altered conditions. The effect of changed conditions on the results is studied to locate any systematic error.

Examples:

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 fractions 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 will be recorded only as 11.3 cm. From an inspection of the recorded value 11.3 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, δl , is 0.05 cm which is half the least 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 results obtained, after averaging over many measurements, be

b = 2.75 cm

t = 2.52 cm and

l = 11.3 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

$b = 2.75 \pm 0.005$ cm

$t = 2.52 \pm 0.0005$ cm

$l = 11.3 \pm 0.05$ cm

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

$V = (11.3 * 2.75 * 0.252) = 7.8309$ 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 δl , δb and δt be δV, then,

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

$V + \delta V$ will correspond to maximum positive values of $\delta l, \delta b, \delta t$,

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

or

$V(1 + \delta V/V) = lbt(1 + \delta l/l)(1 + \delta b/b)(1 + \delta t/t)$

Canceling V = lbt from both sides and using the approximation

(1+x)(1+y)(1+z) = 1+x+y+z as $x \ll 1, y \ll 1, z \ll 1$,

We obtain

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

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

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

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

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

$\delta V/V = 0.0082$

From the value V = 7.8309,

we have

δV = 7.8309 x 0.0082 = 0.064213 cm^{3}or 0.06 cm^3(rounded off to one significant digit).

The result of the measurements is therefore$V = 7.8309 \pm 0.06$ cm^3

An important point to be noted is that writing the volume as 7.8309 cm^3 would convey the idea that the result is measured accurate to 0.0001 cm^3. 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 $\pm$ 6. The volume may be anywhere in the range 7.77 to 7.89 cm^3. As the second decimal place is subject to such an uncertainty, it is meaningless to specify the subsequent digits. The 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 $V = (7.83 \pm 0.06)$ 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

$m = (18.34 \pm 0.005)$ g

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

$d = m/v = 18.34/7.83 = 2.3423$ g cm^{-3}

To estimate the uncertainty in d, we write

$(d + \delta d) = \frac{m+\delta m}{v-\delta v}$

As the **maximum** density will correspond to the greatest **mass and least volume**.

$$d[1+\delta d/d] = \frac{m}{v}\frac{(1+\delta m/m)}{(1-\delta v/v)} 1 + \frac{\delta d}{d} = (1+\delta m/m)(1-\delta v/v)^{-1}$$

As $\delta v/v$ and $\delta v/m$ are very much less than 1,

$$\delta d/d = \delta m/m + \delta v/v$$

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

and

$\delta m/m$=0.005/18.34=0.0003

$\delta d/d$=0.0085

δd= 0.0085 x 2.3423 = 0.02 g/cm^3

Therefore d = (2.3423$\pm$ 0.02) or (2.34 $\pm$ 0.02) g/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 or resolution and not the accuracy. Repeated measurements falling outside the least counts are indicative of this.

Other situation

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.

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

Canceling x = a – b,

$\delta x = \delta a + \delta b$

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

First $\delta(l+m) = \delta l + \delta m.$

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

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

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

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 seconds, in another 50 oscillations take 81 seconds. Is the relative uncertainty the same in both cases? Does the relative uncertainty depend 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 in 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 0.01 mm. 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 cases 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.

LIST OF EXPERIMENTS

1. YOUNG'S MODULUS OF WOOD USING A STRAIN GAUGE

Aim:

To determine the Young's modulus of a wooden scale using a strain gauge.

Apparatus:

A half meter scale with two identical strain gauges fixed to one end of the scale. One strain gauge at the top and the other at the bottom-length wise, a clamp, a circuit board with appropriate terminals to constitute a Wheatstone bridge network, hanger and slotted weights(m = 50 gram), digital multimeter, Vernier calipers,Screw gauge, Decade Resistance Box (D.R.B), constant current source and connecting wires.

Basic Theory:

Young's modulus:-

When an external force (F) is applied along a bar of length(L) (and perpendicular to the cross-sectional area A), internal forces in the bar resist distortion and the bar attains an equilibrium when the external force is exactly balanced by the internal forces with a change in length (ΔL). The tensile stress is force per unit area (in N/m^2) and the longitudinal strain is the change in length to the original length and it is a dimensionless quantity. The ratio of the tensile stress (F/A) to the tensile strain (Δ L/L) is given by,

$$Y = \frac{F/A}{\Delta L/L} \text{..........(1)}$$

Where Y is the young's modulus of the bar.

Strain gauge:

A strain gauge is a transducer whose electrical resistance varies in proportion to the amount of strain in device. The most widely used gauge is metallic strain gauge which consists of a very fine wire or, more commonly metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire of foil subject to strain in the parallel direction as shown in Figure 1.1, the cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson strain. The grid is bonded to a thin backing, called the carrier. The strain gauge is attached directly to the test specimen and responds with a linear change in electrical resistance.

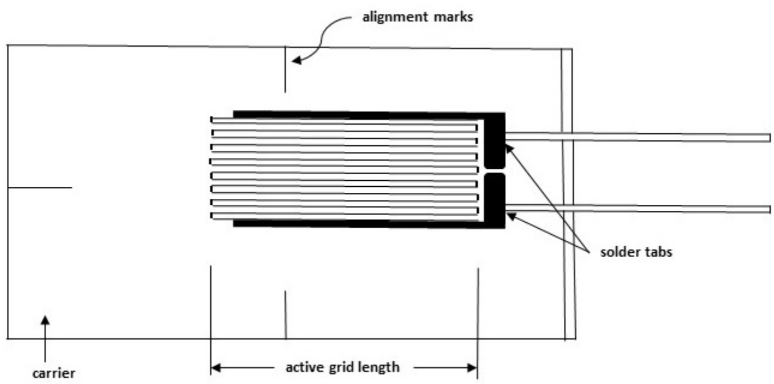


Figure 1.1: Internal structure of strain gauge..

A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (λ). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length.

$$\lambda = \frac{\Delta R/R}{\Delta L/L} \text{........(2)}$$

The gauge factor for metallic strain gauge is typically around 2.

Wheatstone bridge:

Measuring the strain with strain gauge requires accurate measurement of very small changes in resistance and such small changes in R can be measured with a Wheatstone bridge. A general Wheat stone bridge consists of four resistive arms with an excitation voltage,V_{EX} that is applied across the bridge as shown in Figure 1.2.
The output voltage of the bridge V_0, will be equal to;

$$V_0 = [\frac{R_3}{R_3+R_4} - \frac{R_2}{R_2+R_1}] \times V_{EX} .....(3)$$

From this equation, it is apparent that when$R_1/R_2 = R_4/R_3$, when the voltage output V_0 will be zero. Under these conditions, the bridge is said to be balanced. Any change in resistance in any arm of the bridge will result in a non-zero output voltage. Therefore, if we replace R_4 as shown in Figure 1.2 with an active strain gauge, any change in the strain gauge resistance will unbalance the bridge and produce a nonzero output voltage. If the nominal resistance of the strain gauge is designated as R_G, then the strain –induced change in resistance, ΔR can be expressed as,

$$\Delta R = R_G \lambda \text{ Strain}....(4)$$

Assuming that$R_1 = R_2$ and $R_3 = R_G$, the bridge equation above can be rewritten to express V_0/V_{EX} as a function of strain. Ideally, we would like the resistance of the strain gauge to change only in response to applied strain.However, strain gauge material, as well as the specimen material on which the gauge is mounted, will also respond to changes in temperature. Strain gauge manufactures attempt to minimize sensitivity, to temperature by processing the gauge material to compensate for the thermal expansion of the specimen material for which the gauge is intended. While compensated gauges reduce the thermal sensitivity, they do not totally remove it. By using two strain gauges in the bridge, the effect of temperature can be further minimized. For example, in a strain gauge configuration where one gauge is active ($R_G + \Delta R$), and a second gauge is placed transverse to the applied strain. Therefore, a strain has little effect on the second gauge,called the dummy gauge. However, any changes in temperature will affect both gauges in the same way because the temperature changes are identical in the two gauges, the ratio of their resistance does not change, and the effects of the temperature change are minimized.

The sensitivity of the bridge to strain can be doubled by making both gauges active in a half-bridge configuration. Figure 1.2 illustrates a bending beam application with one bridge mounted in tension ($R_G + \Delta R$) and the other mounted in compression ($R_G - \Delta R$). This bridge configuration, whose circuit diagram is also illustrated in Figure 1.2, yields an output voltage that is linear and approximately doubles the output of the bridge circuit.

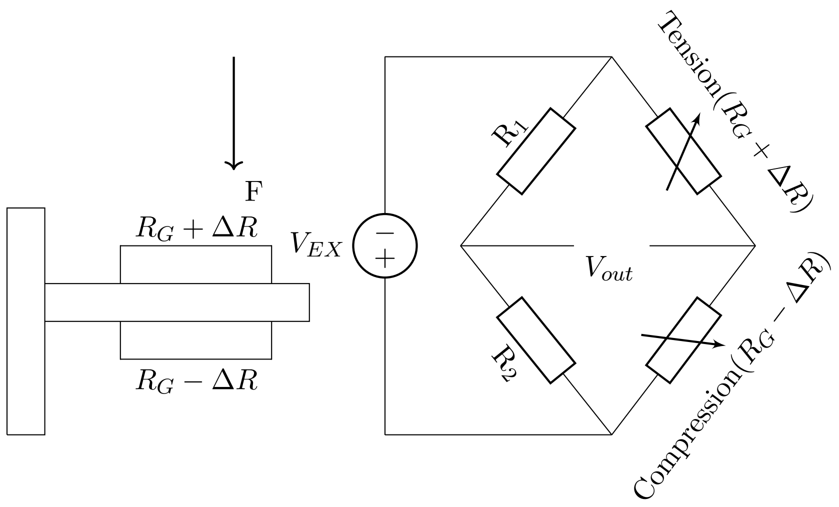


Figure 1.2. Wheatstone network.

In this experiment, we aim to determine the Young's modulus of a half-meter wooden bar by loading it with a mass of m. For a beam of rectangular cross-section with breadth (b) and thickness (d), then the second moment of inertia I_{beam} , is

$$I_{beam} = bd^3/12.........(5)$$

The moment of force or restoring couple is $[\frac{YI_{beam}}{r}]$
Where,

Y is the Young's modulus of the wooden beam

r is the radius of curvature of the bending beam

I_{beam} is the moment of inertia of the beam. The moment of force/restoring couple is Y. I/R where R is the radius of curvature of the bending beam. The Young's modulus Y is calculated by assuming that at the equilibrium, the bending moment is equal to the restoring moment.

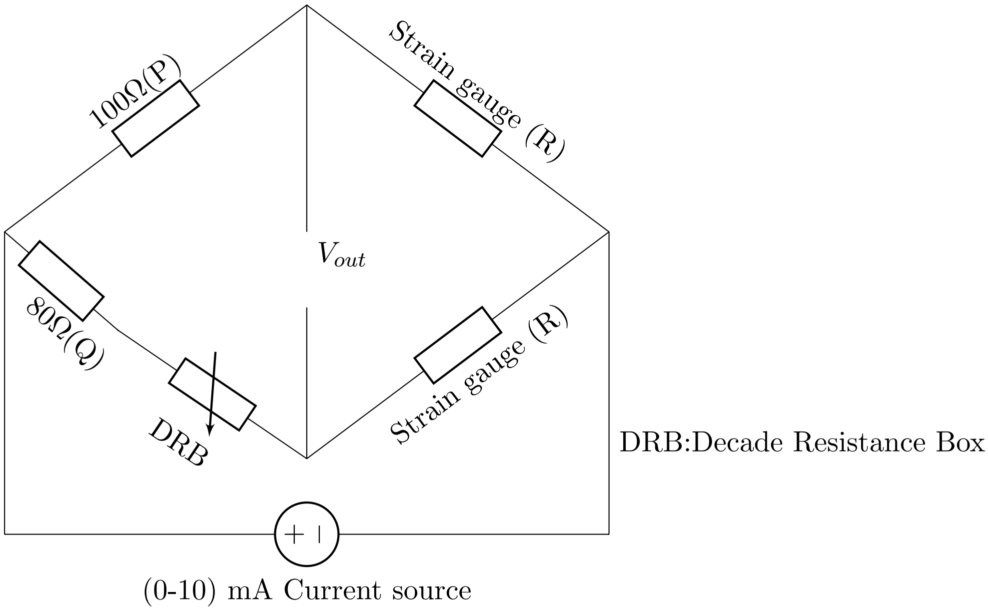


Figure 1.3: Wheatstone bridge circuit diagram.

Procedure:

1. Clamp the beam to the table in such a way that the strain gauges are close to the clamped end. Load and unload the free end of the beam a number of times.

2. Make the connections of the circuit diagram as shown in Figure 1.3.

3. Switch on the constant current source and the digital multimeter.

4. Balance the bridge using Decade Resistance Box (DRB). At this stage the digital multimeter may read 0 or very nearly zero.
   Note: This should be done without any load.

5. At this stage,the system is ready to perform the experiment. Suspend the load with the help of slotted weights with hanger. It is a good idea to keep the load as close as possible to the free end. Note down the voltage with the help of digital multimeter.

6. Increase the load in steps of mass (m = 50 grams), up to 5 m grams and take the readings each time.

7. Unload the beam from 5m grams down to zero in steps of m grams, note the corresponding digital multimeter readings.

8. To check reproducibility, repeat all the above processes, take readings while loading and unloading in steps of m grams.

9. Plot a graph between mass along X-axis and unbalanced voltage dV along Y-axis; obtain the slope of this graph (dV/m).

10. Note the distance between the center of the strain gauges and the point of application of the load (L).

11. Measure the breadth (b) of the beam using slide calipers.

12. Measure the thickness (d) of the beam using a screw gauge.

13. Calculate the Young's modulus (which is nothing but the tensile stress to tensile strain ratio) of the given material with the following expression.(Using 1, 2, 3, 4 & 5).

$$Y = \frac{6Lg\lambda RI}{bd^2[1+R/P](dV/m)}$$

where,

g is acceleration due to gravity,
λ is the gauge factor,
I is the output current from source (S),
R is the resistance of the strain gauge.
P is the resistance used in the circuit.

Note:
1. The breadth of the beam can be measured by using Vernier calipers. Total reading can be found as T.R. = M.S.R. + (V.R × L.C).
2. The thickness of the beam can be measured using screw gauge. Total reading can be found as T.R. = P.S.R. + (H.S.R. ± Z.E.)× L.C.
3. Show calculation for breadth and thickness in separate tables.

Tabulations:

Load (g) ⇒ D.M.M Reading (mV)↓	0	m	2m	3m	4m	5m
Loading (V1)						
Unloading (V2)						
Mean (V1+V2)						

Result & Discussion:
The Young's modulus of a given scale by using strain gauge is: ....N/m^2.

2. RIGIDITY MODULUS OF A WIRE USING TORSIONAL PENDULUM

Aim:

To determine the rigidity modulus of a wire using a torsional pendulum.

Apparatus:

Circular disc suspended from a point using a metal wire about an axis passing through the middle of plate having largest area, two similar weights, a stop watch a meter scale and screw gauge.

Brief discussion and relevant formulae:

The torsional pendulum is the 'angular' version of the simple pendulum. The restoring torque is proportional to the angular displacement. In practice, this will be true only for small angular displacements 'θ' .

One can prove that the time period of torsional oscillations of the system is then given by

$$T = 2\pi\sqrt{\frac{I_{tot}}{C}} = 2\pi\sqrt{\frac{I_0+2I_s+2m_sx^2}{C}}........(1)$$

Where,

I_0= moment of inertia of large disc (without any extra mass)

I_s = Moment of inertia of weight − about an axis passing through its/their own center of gravity, parallel to its length.

m_s= Mass of each solid cylinder (weight).

x = Distance of each weight from axis of suspension.

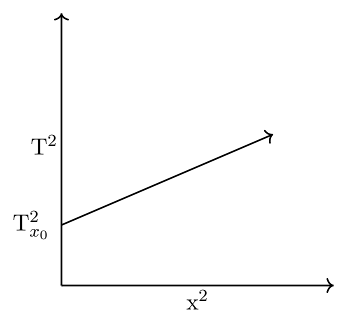
C = Torsional rigidity of suspension wire (couple per unit twist).

Squaring equation(1), we get,

$$T^2 = \frac{4\pi^2}{C}[I_0 + 2I_s + 2m_sx^2] = \frac{8\pi^2 m_s x^2}{C} + \frac{4\pi^2}{C}[I_0 + 2I_s]$$

A graph is plotted between T^2 and x^2. Draw a best fit straight line to data.

Model Graph:



Notes:

1. The suspension wire should be free from kinks.
2. The disc should be horizontal always.
3. Solid weights must be identical.
4. Oscillations should be purely rotational.
5. The wire should not be twisted beyond elastic limits.
6. The time period should be noted carefully by taking the average of about ten periods.
7. Make sure that the angular displacements are small.

Procedure:

1. Take a wire of length (l) and attach one end to the rigid frame with the help of chuck nut, another end to the circular disc.

2. Oscillate the circular disc with a minimum angle of horizontal rotation and note down time taken for 10 oscillations. Calculate the T_0.

3. Keep 200 gram on each side on the circular disc and calculate the time period(T) for 10 oscillations.

4. Plot a graph between T^2 vs x^2. Slope from this graph should be substituted in equation for C. where, T = time period of oscillation with respect to x x = distance of mass from disc

5. Couple per unit twist of suspension wire C is given by

$$C = 8\pi^2 m_s [\frac{\Delta x^2}{\Delta T^2}]$$

6. Determination of I_s and I_0

$$I_0 = 2m_s x^2 \frac{T_0^2}{T^2 - T_{x0}^2} = \frac{2m_s T_0^2}{slope}$$
$$I_s = m_s x^2 \frac{T_{x0}^2 - T_0^2}{T^2 - T_{x0}^2} = m_s \frac{T_{x0}^2 - T_0^2}{slope}$$

I_s And I_0 can be obtained by measuring corresponding time periods.
Let T_0 = time period of large disc alone.
T= time period of oscillations of large disc with masses at distance x.
T_{x0} = time period of oscillation of large disc with masses at x=0,
(obtained from graph i.e. Y-intercept)

Observations:

1. Mass of each of identical added weights m_s =......kg

2. Time period of disc with no masses T_0 = ...s

3. Y- intercept from graph T_{x0}^2 = ...s^2

4. The length of the wire = ...m

Measurements and tabulations:

Distance of Weight from axis of twist (x)cm	x^2 (cm^2)	No. of oscillation (n)	Time taken t (s)	Period T=$\frac{t}{n}$ (s)	T^2 (s^2)
X_1					
X_2					
X_3					
X_4					

Calculations:
1. From the graph obtain $\frac{\Delta T^2}{\Delta x^2}$ = slope,$C = 8\pi^2 m_s[\frac{\Delta x^2}{\Delta T^2}]$ newton per unit twist. Also $C = \frac{\pi\eta r^4}{2l}$ and η is calculated using this formula. (Where r and l are the radius and length of the wire respectively).
2. Compute I_0 and I_s in SI units.

Result & Discussion:
The rigidity modulus of a given wire by using Torsional pendulum=......N/m^2.

3. VERIFICATION OF STEFAN'S LAW AND PLANCK'S CONSTANT

(A) Verification of Stefan's Law:

Aim:

To verify the Stefan's law.

Apparatus:

A kit comprises a D.C. source and meters to measure voltage and current through a circuit.

Introduction:

As we aware, a body kept at a non-zero temperature (absolute temperature) gains heat from the surroundings that are at higher temperature and lose heat to the surroundings at lower temperatures, through radiation. The rate of heat loss to the surroundings depends on the temperature of the body as well as the area of the body. It is also known that the rate of loss of heat is given by the Stefan's law,

$$P = Ae\sigma T^4$$

where,

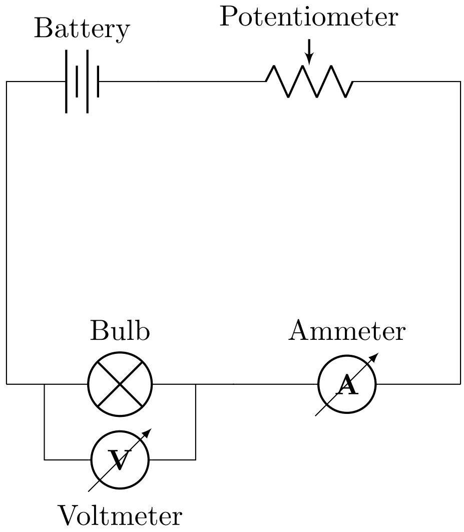
e is the emissivity of the surface of the radiating body,

σ is Stefan's constant,

A is the area of the radiating surface,

In the present experiment, an incandescent bulb is treated as the body kept at high temperatures so that, significant amount of heat is lost by radiation.

Circuit diagram:



Procedure:

1. Make the connections of the circuit diagram as shown in above figure.
2. Switch on D.C. Source adjust voltage, so that the voltmeter (V) reads 0.5 V. Read out the corresponding current (I) through the bulb and record the voltage and current in the tabular column.
3. Calculate the resistance of the filament ($\frac{V}{I}$) and use it as R_0 in your formula, to be used later.
4. Increase voltage in steps of 1 V and find the corresponding current (I).
   Note: Increase the voltage maximum up to 10 V.
5. Calculate the resistance of the filament ($R_T = \frac{V}{I}$) for the various readings taken in step 4.

6. Calculate the corresponding power (P = VI).

7. We know that the resistance of a metal (filament in the present case) at a given temperature T is given as,

$$R_T = R_0 \ (1 + \alpha T)$$

Where,

R_0 is the resistance of the filament at 0°C (273 K) and α is the temperature coefficient of the tungsten filament and its value is 0.0045/°C The temperature of the filament is calculated from the above relation.

Let P be proportional to T^n. In other words,

$$P = (\text{const.})\ T^n$$
$$\text{Log } P = \log\,(\text{const.}) + n \log T$$

Draw a graph of log P *vs* log T. The slope of the graph gives n value.

Precautions:

1. Do not increase the voltage beyond 10 V.
2. Reduce the voltage to zero after the readings are taken and switch off the kit.

Tabulation:

S.No.	Voltage (V)	Current (I)	Resistance $R = \frac{V}{I}$ (Ω)	Power $P = VI$(W)	Temp (K)	log P	log T
1							
2							
3							
4							

Calculations:

Results & Discussion:

(B) Verification of Planck's Constant

Aim:

To determine the Planck's constant.

Apparatus:

Photo Sensitive Device, Light source: Tungsten lamp of 12V/35W, Color filter's: 635nm, 570nm, 540nm, 500nm ,460nm, Regulated Voltage Power Supply, Digital ammeter.

Explanation:

Most of the metals emit electrons under the influence of radiation. This phenomenon was termed as photoelectric emission.

1. The emission process depends strongly on frequency of radiation.
2. For each metal there exists a critical frequency such that light of lower frequency is unable to liberate electrons, while light of higher frequency always does.
3. The number of electrons is proportional to the intensity of this radiation.

The electromagnetic field consists of quanta of energy E=hυ, where υ is the frequency of the radiation and h is the Planck's constant. These quanta are called photons. The electrons are bound inside the metal surface with an energy **ef**, where **f** is called work function. It then follows that if the frequency of the light is such that hυ > ef , it will be possible to eject photoelectron, while if hυ < ef , it would be impossible. In the former case, the excess energy of quantum appears as kinetic energy of the electron, so that,

$$\mathrm{h}\upsilon = \tfrac{1}{2}(\mathrm{mv}^2) + \mathrm{ef}.........(1)$$

Which is the famous photoelectric equation formulated by Einstein in 1905. The energy of emitted photoelectrons can be measured by simple retarding potential technique as is done in this experiment. When a retarding potential V_0 is used to measure kinetic energy of electrons E_e,
we have,

$$E_e = \tfrac{1}{2}(\mathrm{mv}^2) = \mathrm{eV}_0, \text{ and hence } V_0 = \tfrac{h\upsilon}{e} - \mathrm{f}........(2)$$

So, when we plot a graph V_0 as a function of υ , the slope of the straight line yields $\frac{V_0}{\upsilon} = \frac{h}{e}$ and the intercept gives the work function f.

Procedure:

The experimental setup (as shown in Figure 3.1) mainly consists of a light source, a light receiving dark room box with photo tube, a D.C amplifier and five pieces of different color filters. The light source and a receiving dark room are installed on a coattail guide.

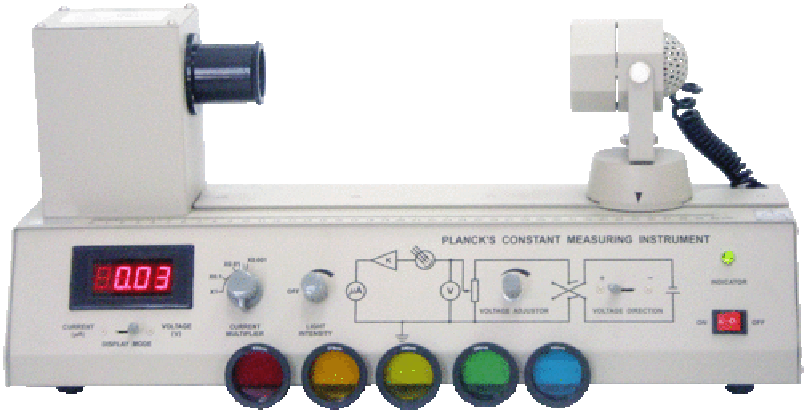


Figure 3.1: Experimental setup for verify the Planks constant.

1. The distance between them may be adjusted from 10-40 cm along the guide. Slide the light source to 250 mm in position and turn on the power.
2. Insert the Red color filter (625nm-635nm) into the drawtube of the receptor. Set the light intensity switch at strong light.
3. Set the voltage direction switch at to negative direction (-)
4. Set the display mode switch at current display, set the accelerator voltage to about 0 V and set the current multiplier at $\times 0.001$.
5. Adjust the accelerator voltage till the photo current decreases to zero and note down this voltage for 635 nm wavelength. Get the V_0 for the other four wavelengths by the same way.
6. Draw a graph as per equation 2, and calculate the Planck's constant (h). The experiment can be repeated for another distance between the light source and the detector.

Tabulation:

S.No.	Wavelength of the colour filter(λ)(nm)	Frequency($\nu = \frac{c}{\lambda}$)(Hz)	Cut off voltage(V_0)(V)
1			
2			
3			
4			

Calculations:

Results & Discussion:

4. SUPERPOSITION PRINCIPLE USING CATHODE RAY OSCILLOSCOPE (CRO)

Aim:

To study the voltage measurements, wave shapes, Lissajous patterns and phase measurement using a CRO.

Apparatus:

A cathode ray oscilloscope, function generators, BNC (Bayonet Neill-Concelman) connectors, R-C network arrangement for phase measurement.

General description of a CRO:

In a cathode ray oscilloscope, a beam of electrons produced by the electron gun is accelerated by an anode and focused onto a fluorescence screen. This beam can be deflected horizontally or vertically by applying a suitable voltage across the X-plates or Y-plates respectively. A linear time-base of any desired frequency can be applied across the X-plates, under whose influence the electron beam travels back and forth horizontally. These x-and y-inputs can also amplify internally.

Procedure:

Preliminary Adjustments:

1. Switch 'ON' power of CRO.
2. Keep the intensity of the CRO low so that the trace on the screen is visible. High intensities may spoil the screen's coating material.
3. Go to 'XY' mode.
4. Keep the Volt/Div knobs of both channels [channel 1 and channel 2] at the same position (say), at 0.2 Volts/Div.
5. Adjust the X-position control and the Y-position control knobs to place the trace at the center of the screen.
6. Switch 'ON' the function generator, keep the frequency of the function generator at 1 KHz.
7. Connect the output of the function generator to the input of channel 1 of the CRO using the BNC connector.
8. Keep to the function switch corresponding Sine wave switched ON.
9. Keep the amplitude coarse control knob at 2 V position and the continuous variation knob at some specific angle so that you see a vertical line trace by the electron beam with a length of about 4 large divisions on the screen.

Can you guess why we are getting a vertical line?

The applied sine wave on Y plates keep changing polarity 1000 times per second in a sinusoidal form and hence the electron beam also, being negatively charged, keep moving up and down at this frequency. Hence due to persistence of vision we see a continuous line. If you reduce the frequency of the applied sine wave using the push button switch on top to very low values (say 0.1Hz) then you can follow the beam movement.

(I) Measurement of A.C. Voltages of different waveforms:

1. The magnitude of the line is proportional to the peak-to-peak voltage of the applied wave (Vpp). Calculate the peak voltage of the sinusoid using formula:

   $$V_p \text{ (V)} = (\text{Number of divisions} \times \text{Voltage sensitivity })/2.$$

   The voltage sensitivity can be read from the knob position of channel 1 in V/div.

2. Calculate $V_{RMS} = \frac{V_p}{\sqrt{2}}$

3. In the digital multimeter, set the function dial to A.C. voltage and the range to 20 V (say). Read the output voltage from the function generator directly with multimeter.

4. Repeat such measurements for two more values.

5. Release the XY mode and adjust the Time/ Div. such that you observe some two or three complete Sine waves within the screen. This is possible because now the time base (Sweep voltage) is applied to the X plates.

6. Set the function knob of function generator to square and then to triangle. Corresponding change in shape can be observed on the CRO screen. calculate the V_{RMS} voltage using both the CRO and the multimeter corresponding to the voltages applied to the square and triangle then tabulate the results.

Table 1. Measurement of A.C. voltages.

S.No.	Shape of the wave	No. of divisions	V$_p$	V_{RMS}(CRO)	V_{RMS} (multimeter)
1	Sine				
2					
1	Square				
2					
1	Triangle				
2					

RMS (Root mean square) value is also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity. It is especially useful when variates are positive and negative, e.g., sinusoids, triangular, square, etc...
The RMS values of sine wave are given by:-

$$V_{rms}^2 = \frac{\nu_p^2}{T}\int_0^t \frac{1-cos(2wt)}{2}dt$$

Consider that,

$$sin^2(wt) = \frac{1+cos(2wt)}{2}$$

we get,

$$V_{rms}^2 = \frac{\nu_p^2}{T}\int_0^t \frac{1-cos(2wt)}{2}dt$$

By solving and substituting the limit values, we get
For SINE wave $V_{RMS} = \frac{V_p}{\sqrt{2}}$
Similarly,
For SQUARE wave $V_{RMS} = V_p$
For TRIANGULAR wave $V_{RMS} = \frac{V_p}{\sqrt{3}}$

Note: The data V_{RMS} (CRO) for square and triangle waves will not agree with those of multimeter Why? Perform integration over one period for the case of sine, square and triangle and derive the relationship between peak voltage and RMS voltage for the different cases given above. Uses the correct relationship obtained by calculation and evaluate the RMS voltage for measurements using CRO. The multimeter results will be erroneous for these cases as it is calibrated only for sine waves.

(II) Lissajous patterns and superposition principle:

1. Set the CRO in XY mode as before. Keep the sensitivity of both channel 1 and channel 2 same (Say,0.2 V/Div).
2. Switch on both the function generators. Set them both at 1 KHz (say). Also, set the output amplitudes of both about the same using the coarse and fine control knobs.
3. Apply the two outputs from the two function generator to the plates channel 1 and channel 2 using BNC cables.
4. Adjust the continuous frequency control dial of one of the function generator and obtain a CIRCLE on the screen. The CIRCLE will keep changing to ellipse and momentarily into a straight line etc. continuously (Why?). This is called the LISSAJOUS PATTERN. The figure CIRCLE shows that the two frequencies applied to X & Y plates are in the ratio 1:1. Sketch the Lissajous figures obtained for the ratios (1: 2, 2:1, 2:3 etc.) by keeping the frequency of one function generator fixed and changing the other continuously. Repeat the experiment for different frequencies and tabulate the results as below in table 2.

Table 2. Measurement of frequency using Lissajous patterns

S.No.	function generator 1	function generator 2	Figure (Draw the figure)	Ratio

(III) Phase measurement using CRO:

1. We know that when an A.C.voltage is applied to R-C combination, it introduces a phase shift. Hence you are given a small R-C combination circuit board for this experiment.
2. Use one function generator only and connect its output to the R-C combination connected in series across its output as shown in figure 4.1. The output from the function generator is connected to channel 1 and the output across the resistor is connected to channel 2 .
3. Set the output frequency to be 1 KHz as before and the amplitude to 1 Volt.
4. Now, you would observe an ELLIPSE on the screen. Adjust the position of the ellipse such that it is properly centered in the screen as shown in figure 4.2.
5. Measure 2A and 2B as shown in figure and calculate $Sin\phi = \frac{B}{A}$.
6. Also calculate $Tan\phi = \frac{1}{wCR}$ = from the known values of the given circuit ($w = 2\Pi f$ C=.....,R=......).
7. Tabulate and compare the phase differences calculated with the two formulae. Interpret the results and comment on the discrepancy, if any, in the readings.

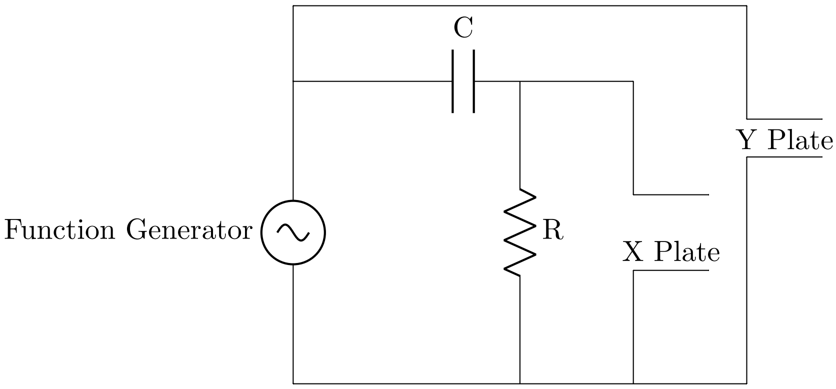


Figure 4.1: Circuit diagram for phase measurement.

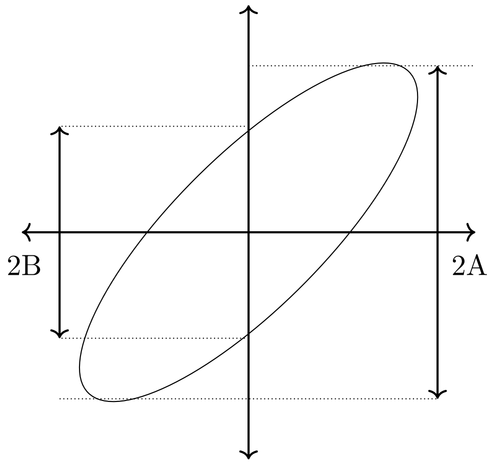


Figure 4.2: Phase diagram.

Table 3. Measurement of the phase difference

S.No.	Frequency(Hz)	R(Ω)	C(μF)	tanϕ	ϕ Calculated	A	B	Sinϕ	ϕ Measured

Results & Discussion:

5. REFRACTIVE INDEX OF A PRISM USING SPECTROMETER

Aim:

To determine the refractive index of the material of a given prism using a spectrometer.

Apparatus:

Spectrometer, spirit level, glass prism, mercury vapour lamp, reading lens, reading light.

Description of the apparatus:

The spectrometer consists mainly of three parts viz. collimator, prism table and telescope.

Collimator:

It consists of an achromatic lens such that the slit is at its focus. The slit is placed in front of a source of light and the width of the slit can be adjusted. The slit acts as an object and the rays coming out of the lens would be parallel when the slit is positioned at the principle focus of the lens.

Prism table:

This table can be adjusted and its position can be read with the help of verniers V1 and V2 fixed diametrically opposite to each other. This table can be rotated about a vertical axis coincides with the axis of rotation of telescope. A prism is placed on the table. A parallel beam of light is incident on the prism and the emergent beam is also parallel.

Telescope:

It is an astronomical telescope fitted with an eyepiece. When a parallel beam of light coming out of the prism falls on the objective, the spectrum produced is viewed through the eyepiece.

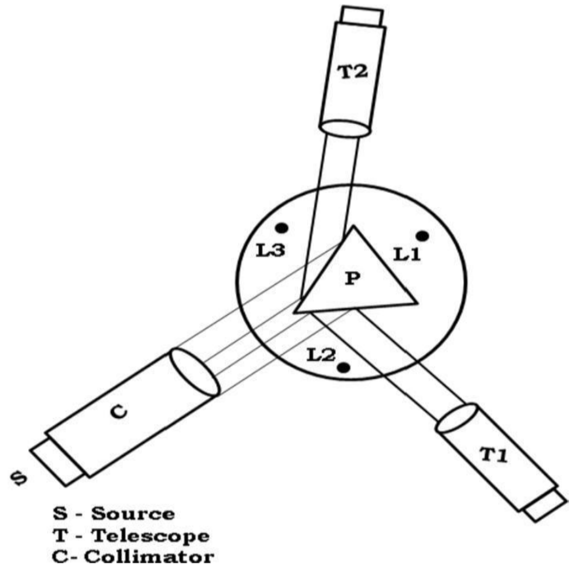


Figure 5.1: Adjustments of Spectrometer for measuring angle of prism.

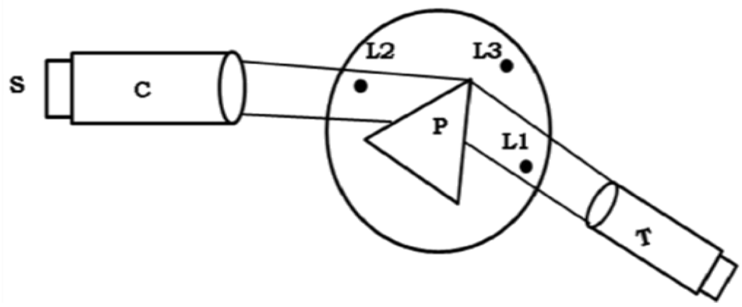


Figure 5.2: Adjustment of Spectrometer for observing dispersion of light.

Procedure:

A. Adjustments of Spectrometer:

1. Adjust the eyepiece of the telescope T so that the cross wires are sharply focused (against the background of a white wall).

2. Focus the telescope for parallel light by viewing a distant object at least 50 m away. See that there is no parallax between the image seen and the cross wires when viewed through the eyepiece.

3. Keep the collimator slit wide ($\sim 0.05mm$) open and let it be as near the mercury lamp as possible.

4. Let the collimator C and telescope T be in a line. Then adjust the collimator to have the slit sharply focused at the eyepiece.

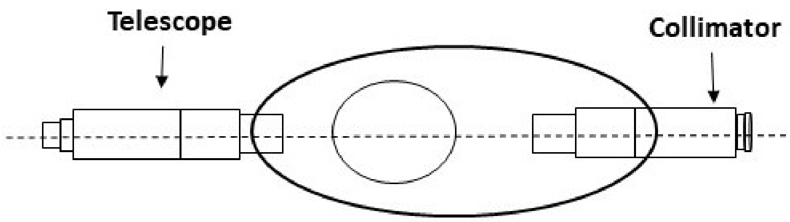


Figure 5.3:Adjustment of collimator to telescope.

5. Leveling the prism table and the prism: Initial adjustment of the prism table must be done using the leveling screws and a spirit level. Place prism P on the table of Spectrometer with one apex near the axis of the table. Turn prism so that the face XY (ground face) is perpendicular to the line joining two of the leveling screws L1 and L2. Turn the prism table so that light can seen reflected from both the faces of the prism at position T1 and T2 of the telescope.(Refer figure 5.2). Setting telescope at T1 adjust L1 or L2.(as the case may be) until the slit image is central in the field of view. Set telescope at T2 and adjust L3 to have the slit image central. Repeat this until the image is at center regardless of the face through which is viewed.

2. Measurement of prism angles:

Narrow the slit as low as possible and carefully set the image of slit at T1 and T2 on the cross wires. Read the angles θ_1 and θ_2 using the verniers attached to the telescope. Thus for left side vernier you will get two readings and for the right side vernier another two readings.

3. Measuring the angle of minimum deviation:

Rotate the table without touching the prism until light is reflected through the sides contain apex X.

Locate the image of slit after refraction and rotate the table keeping the image always in the field of view of the telescope, until the minimum deviation position is reached. At this point the image will stop and go back from the field of view.

Set the table so that the slit is the stationary (stop) position. Use the slow motion screw for accurate setting, after clamping the telescope, at the center of slit, read θ_D both vernier scales (Note that you can repeat by getting another set of θ_D values when light is refracted through then other face of Prism).

Repeat the above process for the different wavelengths available in the spectrum of excited mercury vapour lamp.

Least Count (L.C.) of Spectrometer:

One main scale division (N) =............minute
Number of divisions on Vernier (v) =............
L.C. $=\frac{N}{V}=$ ....sec

Tabulations:

Prism Angle A		**Angle of Minimum Deviation D$_m$**	
Vernier 1	**Vernier 2**	**Vernier 1**	**Vernier 2**
$\theta_1=$ face 1	$\theta_1^{`}=$ face 1	$\theta_{1(Direct\ ray)}=$	$\theta_{2(Direct\ ray)}=$
$\theta_2=$ face 2	$\theta_2^{`}=$ face 2	$\theta_{1(Refracted\ ray)}=$	$\theta_{2(Refracted\ ray)}=$
A$=\frac{(\theta_1-\theta_2)}{2}$	A$=\frac{(\theta_1^{`}-\theta_2^{`})}{2}$	Minimum Deviation D$_m$= $\theta_{1Dir}\sim\theta_{1Ref}$	D$_m$=$\theta_{2Dir}\sim\theta_{2Ref}$
Mean A=		Mean Dm=	

Calculations:
Refractive index of the material of prism is:

$$\mu = \frac{\sin[\frac{A+D_m}{2}]}{\sin[\frac{A}{2}]}$$

VERY IMPORTANT: ALL THE READINGS MUST BE SHOWN IN DEGREES, MINUTES AND SECONDS: FOR EXAMPLE,$18°C30^{'}10^{''}$ AND NOT 18.5°C

Results & Discussion:
1. Angle of prism =...........
2. The refractive index of the material of a given prism (μ) =...........

6. DETERMINATION OF THE RADIUS OF CURVATURE OF A PLANO-CONVEX LENS USING NEWTON'S RINGS METHOD

Aim:

To determine the radius of curvature of the plano convex lens by forming Newton's rings method.

Apparatus:

Plano-convex lens of large focal length, glass plate, monochromatic light source (Sodium vapor lamp) and travelling microscope.

Theory:

The schematic picture of the experimental setup is given in figure 6.1. A Plano-convex lens is placed over a glass plate. The system is illuminated by a monochromatic light from a sodium vapor lamp. Interference fringes are formed due to the superposition of two reflected light rays. One ray is reflected from the lower surface of the lens and another ray is reflected from the glass plate surface. These two rays will interfere with each other and form Newton's rings in the form of circular rings around the point of contact. If these two rays are in same phase they undergo constructive interference, the resultant rings are bright rings and vice-versa.

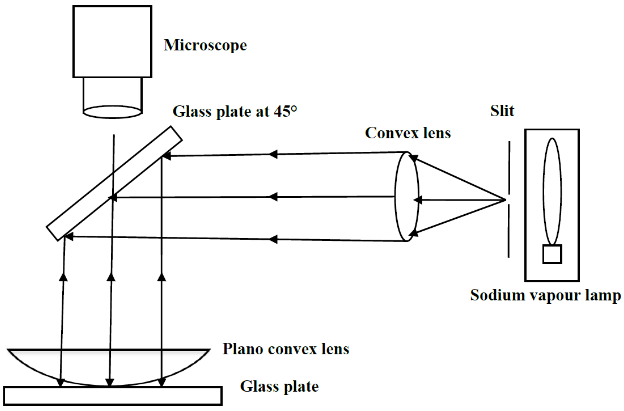


Figure 6.1. Newton's ring setup

Consider a ray of light incident on the air film at a point where its thickness is t as shown in fig.6.2. Taking into account the phase change of Π for reflection at the rarer (air) to denser (glass) surface, the conditions for constructive and destructive interference are formed.

The optical path difference between two reflected rays is (2μtcosr $\pm\lambda/2$). (For air film μ= 1 and for the normal incidence r = 0) Hence in the case, the path difference is (2t + λ /2).

At the point of contact t = 0, and path difference is λ /2 which is the condition of minimum intensity. Thus the central spot is dark. For n^{th} maximum, we have (2t + λ /2) = n λ.

This expression shows that a maximum of a particular order n will occur for a constant value of t. In case of the system, t remains constant along a circle. Thus the maximum is in the form of circle. For different values of t, different maximum will occur. In a similar way, this can be shown that minimum are also in circular form.

2t = (n+1/2)λ (constructive interference or bright rings)

2t = (n) λ(destructive interference or dark rings)

Where,

n (order of rings) = 0, 1,2,3,4...etc.

λ =wavelength of the monochromatic light (589.3 nm)

If R is the radius of curvature of the lens and 'r' is the distance of the point under consideration to the point of contact of the lens and glass plate (see Fig.6.2.)

Then $R^2 = (R-t)^2 + r^2$(From Pythagoras law)

$$R^2 = R^2 - 2tr + t^2 + r^2$$

Since $t^2 << r^2$and D = 2r diameter of the ring.

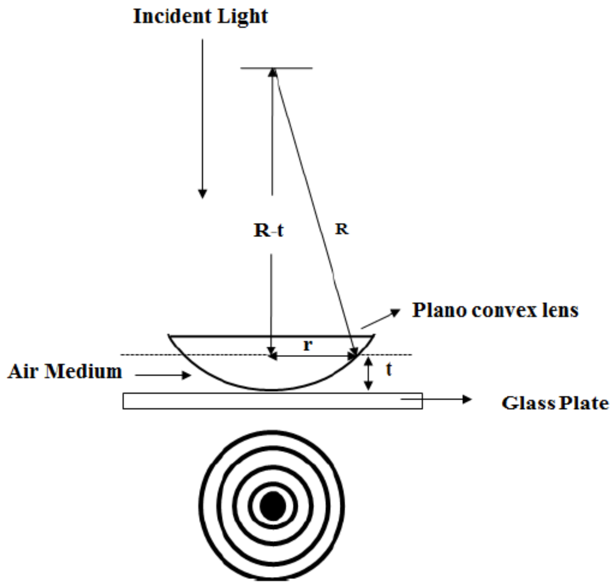


Figure 6.2.Geometry of Newton's rings arrangement

$$2\text{t} = r^2/\text{R}$$
$$2\text{t} = D^2/4\text{R}$$

Combining this with the condition for say the nth dark ring (2t=nλ), one gets for the diameter of that ring.

$$\text{n}\lambda = \frac{D^2}{4R}$$

IfD_{n+m}, andD_n are the diameter of the higher and lower successive dark ring then the wavelength of given source is written by,

$$R = \frac{D^2_{n+m} - D^2_m}{4\lambda n}$$

Procedure:

1. Adjust the microscope such that there is no parallax error between the cross wire and the rings.
2. Rotate the eyepiece such that one of the cross wire passes through the central spot of the ring system and the other tangential to one of the rings.
3. As the microscope is moved along the horizontal scale, the tangential cross wire coincides with the different successive rings.
4. By placing the cross wire tangential to a particular ring at the two extremities and note down the scale readings, the diameter of the ring may be determined.
5. Starting from the left most (say15^{th}) dark ring, move the cross wire outward to one side by counting the number of dark rings.
6. Take the reading on the horizontal scale. Move the cross -wire towards the center and take readings at the position of every dark ring.
7. Continue the readings on the other side up to the 15^{th} ring for the same orders. Then difference between the two sides of the readings of a particular order of the ring gives the diameter of that particular ring.
8. Draw a graph with order n on X-axis and (diameter)^2 along Y-axis (Shown in Fig.6.3 Model graph)

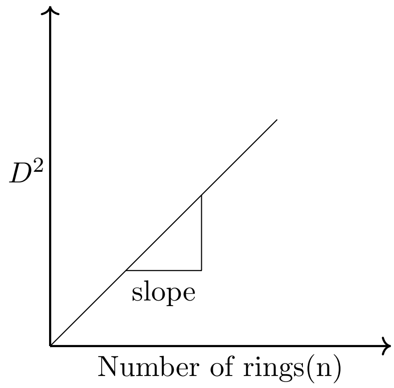


Figure 6.3: Model graph.

Tabulations:

Order of ring (n)	X_{Left} (cm)	X_{Right}(cm)	Diameter(cm)	(Diameter)^2(cm^2)
15				
.				
.				
1				

Results & **Discussion:**

1.The radius of curvature of a plano-convex lens........cm.

7. DETERMINATION OF WAVELENGTH OF LIGHT BY STUDYING DIFFRACTION FROM A SCALE.

Aim:

To determine the wavelength of the laser beam using diffraction from a scale.

Apparatus:

A laser source (He-Ne laser), a stainless steel scale preferably graduated in millimeters, optical bench, wooden scale.

Theory:

The diffraction grating is an array of N parallel equidistant slits.
When a beam of monochromatic light of wavelength (λ), falls on a grating, an intensity pattern results, consists of a series of interference fringes. The angular separation of these fringes are determined by the ratio (λ /d), where 'd' is the spacing between the centers of adjacent slits. The relative intensities of these fringes are determined by the diffraction pattern of the single grating slit, which depends on the ratio λ /a, where 'a' is the slit width.

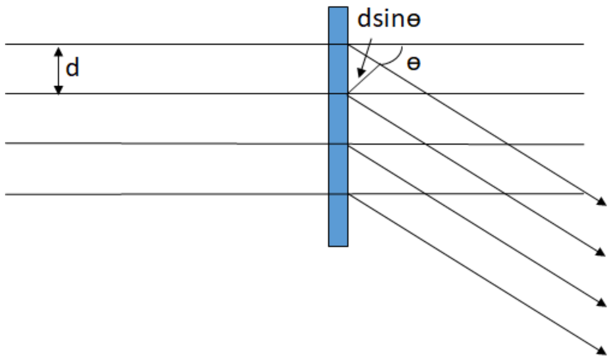


Figure 7.1: Diffraction of light from the grating.

The laser beam is incident at grazing incidence on the scale. The diffraction pattern is observed at large distance from the scale. This is called fraunhofer diffraction. The pattern arises due to diffraction at engravings of the scale, and is governed by the following grating equation.

$$d(sin\theta_i - sin\theta_m) = m\lambda....(1)$$

Where 'd' is the engraving separation, λ is the wavelength of light, θ_i is the angle of incidence and θ_m is the angle of diffraction for m^{th} order. For m=0 the beam is specularly reflected.

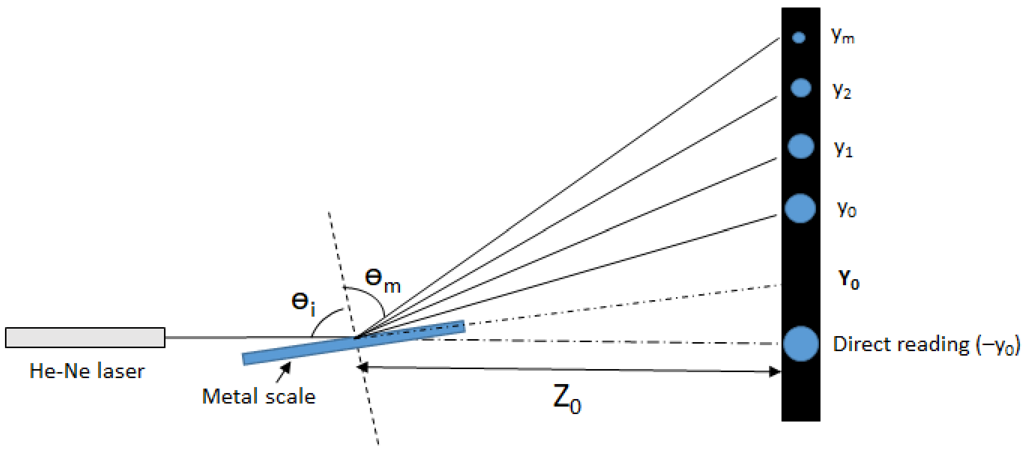


Figure 7.2: Schematic of diffraction pattern formed due to the incidence of laser beam on metal scale.

Procedure:

1. Place the metal scale on the optical bench and align such that the laser beam falls at grazing incidence.
2. Align scale position accordingly to get the diffraction pattern on a screen.
3. Measure the distances Y_m of the position of m^{th} order diffraction spot from the horizontal plane (i.e., the plane in which the scale lies).
4. Mark the position of the direct beam(-y_0) (in the absence of scale) on the screen, and note the position of the diffraction spots (in the presence of scale).the average distance between the direct beam position and 0^{th} order spot(y_0) will give the reduced position(Y_0).
5. These distances can be measured from the wooden scale placed as a screen. The distance (Z_0) between the point of incidence laser on the scale and screen can be measured with a meter scale.
6. The data can be tabulated as given below table.

Observations:

Least count of the metal scale d = ...

Distance between metal scale to screen Z_0=.......

$$Y_0 = \frac{y_0+(-y_0)}{2}$$

Tabulations:

Observations		Position(y_m)	Reduced Positions Y_m=y_m-Y_0	Y_m^2
S.no	Order of the fringes (m)			
1	Direct Beam	- y_0		
2	m=0	y_0	Y_0=y_0-Y_0	
3	m=1	y_1	Y_1=y_1-Y_0	
4	m=2	y_2	Y_2=	
5	m=3	y_3	Y_3=	
6	m=4	y_4	Y_4=	
7	m=5	y_5	Y_5=	

Plot Y_m^2 and m, and obtain its slope.

Calculate,

$$\lambda = \frac{d}{2Z_0^2}(Slope)$$

Results & Discussion:

The wavelength of the laser beam (λ) =..........nm

8. MAGNETIC FIELD ALONG THE AXIS OF A CIRCULAR COIL

Aim:

To measure the magnetic field along the axis of a circular coil carrying current and to calculate the horizontal component of the earth's magnetic field.

Apparatus:

Stewart & Gee's apparatus, D.C. power supply, ammeter, Commutator, plug key, connecting wires, etc.

Theory:

For a current 'I' going around a circular loop of wire of radius 'r', the strength of the magnetic field along the axis of the circular loop is given by

$$B(x) = \frac{\mu_0 I r^2}{2(x^2+r^2)^{3/2}}$$

This equation assumes S.I. units, so the current is in amperes, distances are in meters, and the magnetic field is in tesla (T). The constant $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$. Notice that along the axis of the circular loop, the magnetic field is parallel to the axis. Its relationship to the current in the circular loop is given by right hand rule. Curl the fingers of your right hand around the circular loop so they point in the direction of the current; your thumb then gives the direction of the magnetic field along the axis of the circular loop. If instead of a single circular loop there are 'n' turns of a coil in the form of a circular loop, then magnetic field is a simply n time the magnetic field due to a single loop.

$$B(x) = \frac{\mu_0 I n r^2}{2(x^2+r^2)^{3/2}}$$

If the tangent – galvanometer (compass box) is set such that the plane of the coil is along the magnetic meridian i.e. B is perpendicular to B_H (B_H is the horizontal component of the earth magnetic field), the needle rests along the resultant. From tangent law, one can write,

$$B(x) = B_H Tan\theta$$
(or)
$$B(x) \propto Tan\theta$$
$$Tan\theta = \frac{B(x)}{B_H}$$

Procedure:

1. Use the given compass box to find the east and west directions. Now the plane of the circular coil is said to be parallel to the magnetic meridian. (orient the apparatus such that the coil plane is in north-south plane and the axis of circular coil along east-west direction) as shown in the figure 8.1.

2. Place the compass box exactly at the center of wooden sliding bench, and make sure that the compass is moving freely.

3. Now rotate the compass box so that the compass needle comes close to zero and now again slowly move or readjust the wooden sliding bench till the pointer shows 0-0 reading.

4. Now switch on the power supply and adjust the current(0.5A) so that the deflection is about $60^0 - 70^0$, note down the deflection on the compass box it as (θ_1 and θ_2). Figure 8.1: Experimental setup for the measurement of field along the axis of a current carrying coil.

5. Reverse the current using commutator and record the values of θ_3 and θ_4 .

6. Move the compass box at intervals of 2 c.m. along the axis until the value of the field drops to 10% of its value at the center of the coil and note the deflections θ_1,θ_2, $\theta_3$and θ_4 in each case.

7. Repeat the experiment for a few currents.

8. Draw the graph (e.g. as shown in the figure 8.2) of Tanθ Vs. B(x) and calculate the horizontal component of the earth's magnetic field (B_H) from the slope of the graph. The experiment is to be performed only on one side of the coil.

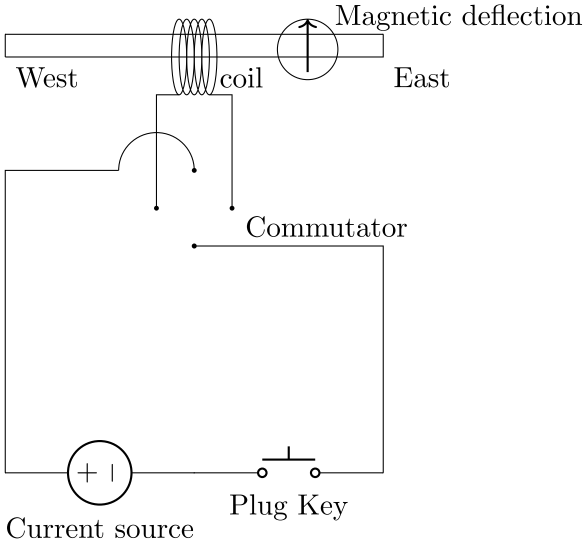


Figure 8.1: Experimental setup for the measurement of field along the axis of a current carrying coil.

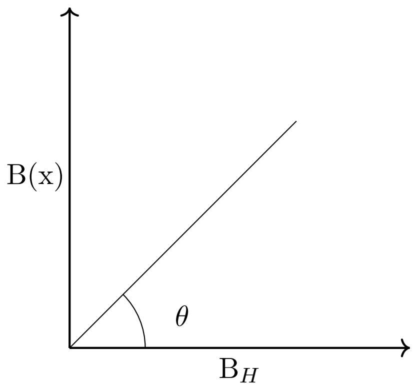


Figure 8.2: Model graph.

Observations:

No. of turns of the coil n = ...
Radius of the coil r = ...
Current in the coil I = ...
Magnetic permeability of the free space $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$.

Tabulations:

S.No	Distance(x) cm	Deflections(θ) (degrees)					Magnetic Field B(x)	Tanθ
		θ_1	θ_2	θ_3	θ_4	Mean θ		

Graph:

1. Plot a Graph between B(x) Vs. X .
2. Plot a Graph between B(x) Vs. Tanθ and Calculate the horizontal component of the earth's magnetic field (B_H).

Precautions:

1. Don't pass higher current through the coil.
2. If the power supply shows the overload switch off the power supply and minimize your input current value or increase the load by using more number of turns.
3. Make sure there is no magnetic material near the deflection magnetometer.
4. Carefully connect the commutator and plug key in the circuit, such a way that the current source terminal should not be shorted.

Results & Discussion:

The horizontal component of the earth's magnetic field (B_H) =................

9. DETERMINATION OF ENERGY GAP OF A SEMICONDUCTOR

Aim:

To determine the energy gap (band gap) of a given semiconductor.

Apparatus:

A semiconductor diode, a low voltage power supply, an oven to heat the semiconductor diode, an oil bath and thermometer.

Theory:

For a semiconductor diode at 0K the valence band is completely filled and the conduction band is empty and it behaves as an insulator. If the temperature is increased, some of the valence electrons gains thermal energy greater than the forbidden energy (E_g) and it moves to conduction band, which constitutes some current to flow through the semiconductor diode.

When reverse bias is applied to the semiconductor diode, minute current is possible due to movement of minority carriers. The diode current initially increases with the applied voltage and saturates at slightly higher voltage. The current which is independent of the voltage is called saturation current and mainly depends on temperature. The temperature dependence of saturation current can be written approximately in the form

$$I_0=[const]\varrho^{\frac{-E_g q}{\eta K_B T}}$$

$$E_g = (0.1725 \text{ x Slope}) \text{ eV}$$

$$\text{slope}=\frac{lnI_0}{1000/T}$$

Where,

I_0 is reverse saturation current.

K_B is Boltzmann constant ($1.3806\times10^{-23}m^2KgS^{-2}K^{-1}$).

E_g is energy band gap in electron volts.

η is junction constant (typically around 2 for diodes, 1 for transistors).

q is charge of electron ($1.6\ \times10^{-19}C$).

T is temperature in Kelvin.

Experimental set-up:

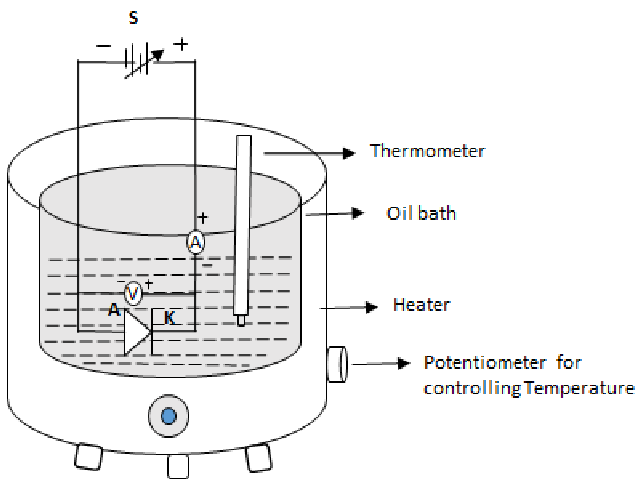


Figure 9.1:Energy gap experiment setup diagram.

Procedure:

1. Switch ON the diode kit.
2. Connect the diode under investigation to jack marked diode circuit is connected for diode in reverse bias.

3. Adjust the current through the diode for a convenient value, say 1μA by varying the potentiometer.
4. Place the oil filled beaker in oven. Switch ON the oven (shown in above figure 9.1) and heat the oil up to 50°C then switch off the oven. (even though the temperature of oil raises up to 100°C
5. Measure the temperature using the thermometer.
6. Now place the diode in the oil and take the current across the diode as a function of temperature, at least 20 measurements in the range 35°C to 100°C.
7. Remove diode from the oil bath after completing your reading.
8. Tabulate the readings.
9. Draw a graph between (shown in the below figure 9.2) lnI_0 Vs 1000/T.

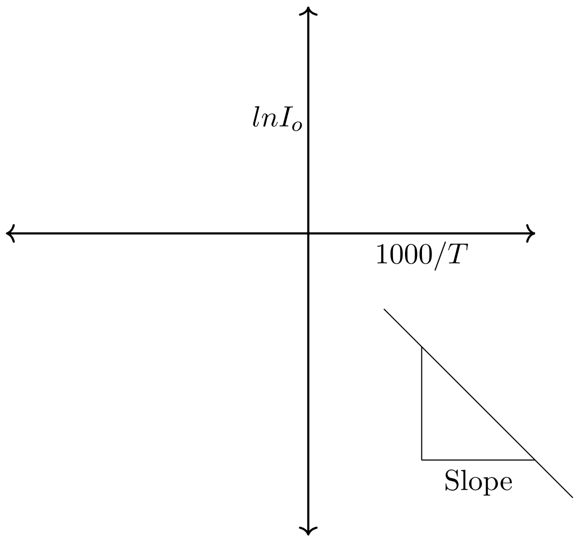


Figure 9.2: Model graph.

Precautions:

1. Graduation on energy regulator knob does not indicate the temperature. They simply indicate the ON and OFF time of the heater.
2. Do not heat oil more than 50°C.
3. If a thermometer breaks, inform your instructor immediately. Do not touch either the mercury or the glass with your bare skin.

Tabulation:

S.No.	Temperature (°C)	Temperature (K)	1000 / T	$I_0(\mu A)$	ln I_0

Results & Discussion:

Energy gap (E_g) of the given semiconductor is = ...eV.

10. CHARACTERISTICS OF ZENER DIODE AND BIPOLAR JUNCTION TRANSISTOR (BJT)

Aim:

(A)To study the voltage-current characteristics of a Zener diode.

(B)To study the input-output characteristics of a Bipolar Junction Transistor(BJT) and calculate the input dynamic resistance from input characteristics and output dynamic resistance from output characteristics and current gain from transfer characteristics.

Apparatus:

Zener Diode (Kit), Bipolar Junction Transistor (Kit), Connecting wires.

Introduction:

(A) Zener diode:

A zener diode is a special kind of diode which permits current to flow in the forward direction as normal, but will also allow a large current to flow in the reverse direction when the voltage is above a certain value the breakdown voltage known as the zener voltage.

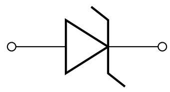


Figure 10.1: Zener diode symbol.

Zener diodes are widely used to regulate voltages in circuits. When connected in parallel with a variable voltage source so that it is reverse biased, the zener diode conducts when the voltage reaches the diode's reverse breakdown voltage thereby controlling the voltage.

(B)Transistor:

A Bipolar Junction Transistor (B.J.T.) is a three-terminal device constructed with doped semiconductor material and may be used in amplifying or switching applications. Bipolar transistors are so named because their operation involves both electrons and holes, as opposed to unipolar transistors, such as field effect transistors, in which only one carrier type is involved in charge flow. Although a small part of the transistor current is due to the flow of majority carriers, most of the transistor current is due to the flow of minority carriers and so B.J.Ts are classified as minority carrier devices.

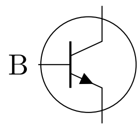


Figure 10.2: NPN Transistor symbol.

The following conventions are used in the nomenclature:

i) V_{BE} - Base to emitter voltage
ii) V_{CE} - Collector to emitter voltage
iii) I_B - Base current
iv) I_C - Collector current

Input Characteristics:

The input voltage V_{BE} is varied and the corresponding input current I_B is noted, keeping V_{CE} constant. The input characteristics are similar to the forward biased characteristics of p-n junction diode. Curves of input characteristics can be drawn for different values of V_{CE}. When V_{CE} is increased, it produces greater depletion region in the collector-base junction. This reduces the distance between CB and EB depletion regions. Consequently, more of the charge carriers from the emitter flow across the CB junction, and fewer flow out via the base terminal and base current decreases.

Output Characteristics:

In plotting output characteristics, I_B is maintained constant at several convenient levels. V_{CE} is adjusted in steps, and the I_C is measured. For each value of I_B, I_C is plotted versus V_{CE} to give a family of characteristics. I_C increases slightly to some extent with increasing V_{CE} although I_B is held constant. I_C reduces to zero when V_{CE} becomes zero.

Procedure:

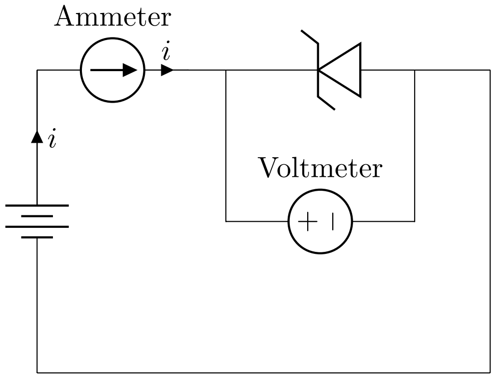


Figure 10.3: Zener diode reverse bias circuit diagram.

1. Connect the zener diode in reverse bias as shown in the figure 10.3.
2. Turn on the power supply and adjust it such that V is 0.5 V, note I_z from the milliammeter.
3. Increase V in steps of 0.5 V up to 9.0 V, by adjusting V and note the corresponding I_z values. Tabulate the readings.
4. Draw the graph by plotting the V values in negative X-axis and I_z values in negative Y-axis.
5. Determine the zener breakdown voltage (V_z) from the graph.

Tabulation:

S.No	Reverse Bias	
	V(volt)	I(mA)

(B) Transistor:

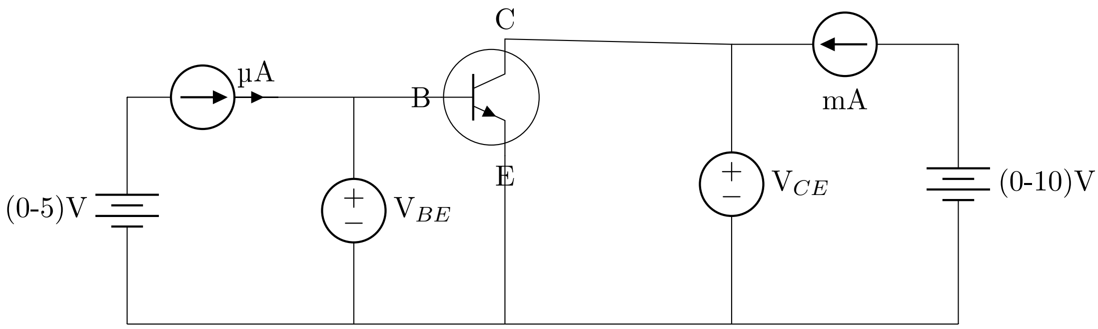


Figure 10.4: Common emitter configuration circuit diagram.

Procedure:

Connect the transistor in common emitter (CE) configuration circuit a shown in the figure 10.4.

(a) Input Characteristics:

In this the collector emitter (V_{CE}) voltage is fixed and base current (I_B) is measured as the base to emitter voltage (V_{BE}) is varied in steps.

1. Keep the voltage V_{CE} = 1 volt.
2. Increased V_{BE} in steps of 0.05 volts and note down I_B.
3. Take care that the V_{CE} remains constant.
4. Take different sets of readings for different values of V_{CE} (i.e. V_{CE} = 1V and V_{CE} = 5V).
5. Plot graph (e.g. as shown in figure.10.5) of I_B (along Y-axis) against V_{BE}(Along X-axis).

Tabulation:

S.no	V_{CE}= 1V		V_{CE}= 5V	
	V_{BE}(v)	I_B (µA)	V_{BE}(v)	I_B(µA)

(b) Output Characteristics:

In this the base current (I_B) is fixed and collector current (I_C) is measured as the collector to emitter voltage (V_{CE}) is varied in steps.

1. Set the base current (I_B) to 20 micro-amps by adjusting V_{BE}.
2. Vary collector to emitter voltage (V_{CE}) and note down the value of I_C for different values of V_{ce}.
3. Increase the I_B value into 40 micro-amps and repeat step 2.
4. Plot graph (e.g. as shown in figure 10.6) of I_C (along Y-axis) against V_{CE} (along X-axis) for different values of I_B.

Tabulation:

S.no	I_B= 20(µA)		I_B= 40 (µA)	
	V_{CE} (V)	I_c (mA)	V_{CE} (V)	I_C(mA)

(c) Transfer characteristics:

In this case, we study the variation of I_C Vs. I_B, e.g., input Vs. output.

1. Adjust V_{CE} to 5 volts.
2. Vary I_B from 0 up to 150 micro amps in steps of 10 micro amps and note down respective values of I_C.
3. Repeat step 2 for different values of V_{CE}.
4. Plot graph of I_C (along Y-axis) against I_B (along X-axis) for different values of V_{CE}.

Tabulation:

S.no	V_{CE}= 5V		V_{CE}= 10V	
	I_B(µA)	I_C (mA)	I_B(µA)	I_C(mA)

Model Graphs:

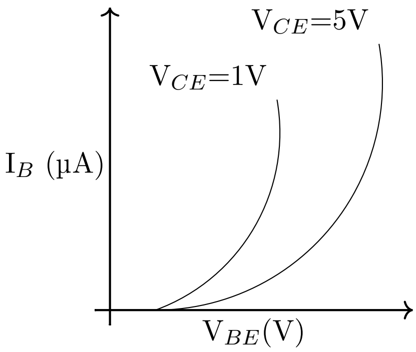


Figure 10.5: Input characteristics

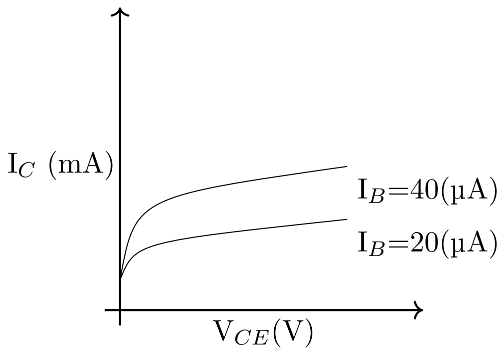


Figure 10.6: Output characteristics

Results & Discussion:

(A) Zener diode:

The Zener breakdown voltage = ...Volts.

(B) Transistor:

(a) INPUT CHARACTERISTICS:

$$\text{Input resistance} = \frac{\Delta V_{BE}}{\Delta I_B} \text{ at } V_{CE} \text{ constant.}$$

(b) OUTPUT CHARACTERISTICS:

$$\text{Output resistance} = \frac{\Delta V_{CE}}{\Delta I_C} \text{ at } I_B \text{ constant.}$$

(c) CURRENT GAIN:

$$\text{Current gain } \beta = \frac{\Delta I_C}{\Delta I_B} \text{ at } V_{CE} \text{ constant.}$$