APPLIED PHYSICS LABORATORY

Common to CSE, AI, DS, ADS & IT First Year

PHYSICS
Vignan's Institute of Information Technology, Visakhapatnam

INTRODUCTION

Physics is a knowledge based on experiments and in physics education experiments play an important role to start knowledge formation and conceptualization. The verificatory role of experiments is the preferred physicists' stance, as expressed by Feynmann et. al. (1963)

> *"The test of all knowledge is experiment. Experiment is the sole judge of scientific truth".*

Recent reforms of physics education also emphasize on developing effective methods in which experiments are conducted in the physics curriculum and utilizing experiments complimentarily in class room teachings. The aim of this laboratory is to give the students an opportunity to learn and verify the physical laws using experimental apparatus/tools in the real world and expose students to the scientific methods and instruments of physical investigations.

In Engineering Physics course there are three components- lecture, tutorial and laboratory. In EP laboratory each experiment offers learning of an important law of physics which will be discussed in lectures and tutorials. Since different lab sections meet on different days of the week and each group of students do different experiment on their turn, few students may deal with the concepts before it discussed in lecture. In this case, the lab will serve as an introduction to the lecture. In other cases the lecture will be an introduction to the lab.

<u>Instructions to the students</u>

1. No student will be allowed after 5 min of commencement of laboratory.
2. The students should attend the lab neatly with proper prescribed uniform
3. Before any cycle of experiments, a class is spent on demonstrating those experiments. The students should not miss that class for any reason and they have to be very attentive in that class.
4. They should read the procedure thoroughly for the lab experiment from the manual and come well prepared
5. Student should bring the following material to the lab: Record book/Sheets, pen, pencil, ruler, instruction manual, graph sheets, calculator and any other stationary item required. **PENCIL is to be used only for plotting the graphs. Readings should be noted with PEN only.** Students are not supposed to exchange any of the above items during the experiment.
6. Students should not bring drink or food items in the lab.
7. Usages of mobile phones are not allowed during the lab classes
8. They should not go to others table leaving their place without taking permission from the staff. They should maintain silence in the class
9. During the experiment, at least one set of observations should be signed by the instructor. **An unsigned observation will be awarded to ZERO marks.**
10. You are expected to perform the experiment, complete the calculation and data analysis during the laboratory hours**. <u>Submit the record to the lab assistant with in two days after the experimentation</u>; late submission may lead to loss of marks**. No marks will be awarded to the experiment after 4 days of the laboratory session.

11. **Copying and manipulation of experimental data/lab reports are strictly prohibited.**
12. All the students should maintain above 75% of the attendance, students having <75% of the attendance is not permitted to write External Examination.
13. Each batch (30 students) are assigned to one Lab instructor (faculty), all the students are instructed to follow the same faculty till the end of the semester. Concern faculty is responsible for the record correction and awarding marks for each experiment.
14. Each batch will be divided into sub batches and one student will act as a batch lead. **Batch lead will be responsible for the apparatus collection and resubmission to the lab assistant.** If anyone failed to return the apparatus in the proper condition, the complete batch is liable to impose fine.
15. **Safety Procedures In the lab:**

    (i) Be aware of power supplies to experimental set-ups. Before connecting/detaching power cord of instruments, please ensure power point is switched OFF.

    (ii) Be aware of sharp/pointed edges of blades/instrument.

Declaration

I hereby declare that, I have read all the rules and regulations given above and I will accept the punishment given by the lab Incharge if I fail to obey them.

Signature of the Student

LIST OF EXPERIMENTS

1. MEASUREMENTS AND ERROR ANALYSIS
2. DIFFRACTION GRATING -SPECTROMETER
3. DIFFRACTION GRATING -WAVELENGTH OF A LASER
4. NUMERICAL APERTUTE
5. ZENER DIODE
6. p-n JUNCTION DIODE
7. THERMISTOR
8. SOLAR CELL
9. HALL EFFECT
10. PLANKS CONSTANT
11. FULL ADDER AND HALF ADDER

EXPERIMENT 1

MEASUREMENT AND ERROR ANALYSIS

1. Introduction:

"A measurement result is complete only when accompanied by a quantitative statement of its uncertainty. The uncertainty is required in order to decide if the result is adequate for its intended purpose and to ascertain if it is consistent with other similar results." National Institute of Standards and Technology

All measurements have some degree of uncertainty that may come from a variety of sources. The process of evaluating this uncertainty associated with a measurement result is often called *uncertainty analysis or error analysis*.

The complete statement of a measured value should include an estimate of the level of confidence associated with the value. Properly reporting an experimental result along with its uncertainty allows other people to make judgments about the quality of the experiment, and it facilitates meaningful comparisons with other similar values or a theoretical prediction. Without an uncertainty estimate, it is impossible to answer the basic scientific question: "Does my result agree with a theoretical prediction or results from other experiments?" This question is fundamental for deciding if a scientific hypothesis is confirmed or refuted.

When we make a measurement, we generally assume that some exact or true value exists based on how we define what is being measured. While we may never know this true value exactly, we attempt to find this ideal quantity to the best of our ability with the time and resources available. As we make measurements by different methods, or even when making multiple measurements using the same method, we may obtain slightly different results. So how do we report our findings for our best estimate of this elusive true value? The most common way to show the range of values that we believe includes the true value is:

$$\text{Measurement} = \text{Best estimate} \pm \text{Uncertainity (Units)}$$

Finally, we will be trying to compare our calculated values with a value from the text in order to verify that the physical principles we are studying are correct. Such comparisons come down to the question "Is the difference between our value and that in the text consistent with the uncertainty in our measurements?".

The topic of measurement involves many ideas. We shall introduce some of them by means of definitions of the corresponding terms and examples

Sensitivity - The smallest difference that can be read or estimated on a measuring instrument. Generally, a fraction of the smallest division appearing on a scale. About 0.5 mm on our rulers. This results in readings being uncertain by at least this much.

Variability - Differences in the value of a measured quantity between repeated measurements. Generally due to uncontrollable changes in conditions such as temperature or initial conditions.

Range - The difference between largest and smallest repeated measurements. Range is a rough measure of variability provided the number of repetitions is large enough. Six repetitions are reasonable. Since range increases with repetitions, we must note the number used.

Uncertainty - How far from the correct value our result might be. Probability theory is needed to make this definition precise, so we use a simplified approach. We will take the larger of range and sensitivity as our measure of uncertainty. Example: In measuring the width of a piece of paper torn from a book, we might use a cm ruler with a sensitivity of 0.5 mm (0.05 cm), but find upon 6 repetitions that our measurements range from 15.5 cm to 15.9 cm.

Our uncertainty would therefore be 0.4 cm

Precision - How tightly repeated measurements cluster around their average value. The uncertainty described above is really a measure of our precision.

Accuracy - How far the average value might be from the "true" value. A precise value might not be accurate.

For example: a stopped clock gives a precise reading, but is rarely accurate. Factors that affect accuracy include how well our instruments are calibrated (the correctness of the marked values) and how well the constants in our calculations are known. Accuracy is affected by systematic errors, that is, mistakes that are repeated with each measurement. Example: Measuring from the end of a ruler where the zero position is 1 mm in from the end.

Blunders - These are actual mistakes, such as reading an instrument pointer on the wrong scale. They often show up when measurements are repeated and differences are larger than the known uncertainty.

Example: recording an 8 for a 3, or reading the wrong scale on a meter.

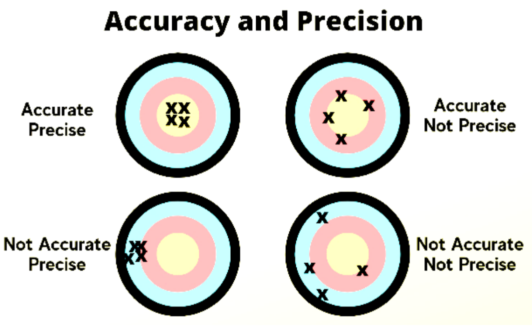


Figure 1 illustrate the difference between accuracy and precision

Comparison - In order to confirm the physical principles, we are learning, we calculate the value of a constant whose value appears in our text. Since our calculated result has an uncertainty, we will also calculate a Uncertainty Ratio (UR) which is defined as

$$\text{Uncertainity ratio} = \frac{|\text{experimental value} - \text{theoritical value}|}{\text{Uncertainity}}$$

A value less than 1 indicates very good agreement, while values greater than 3 indicate disagreement. Intermediate values need more examination. The uncertainty is not a limit, but a measure of when the measured value begins to be less likely. There is always some chance that the many effects that cause the variability will all affect the measurement in the same way.

Example: Do the values 900 and 980 agree?

If the uncertainty is 100, then UR= $80/_{100}$ = 0.8 and they agree,

but if the uncertainty is 20 then UR = $80/_{20}$= 4 and they do not agree.

2. Combining measurements

Consider a simple function $\boldsymbol{R = a.b}$, $\boldsymbol{a}$ and $\boldsymbol{b}$ have uncertainties of $\Delta\boldsymbol{a}$ and $\Delta\boldsymbol{b}$, then

$$\Delta\boldsymbol{R} = (\boldsymbol{a} + \Delta\boldsymbol{a})(\mathbf{b}+\Delta\boldsymbol{b}) - \boldsymbol{ab} = \mathbf{a}\Delta\boldsymbol{b} + \boldsymbol{b}\Delta\boldsymbol{a} + \Delta\boldsymbol{a}\Delta\boldsymbol{b}$$

Since uncertainties are generally a few percent of the value of the variables, the last product is much less than the other two terms and can be dropped. Finally, we note that dividing by the original value of **R** separates the terms by the variables

$$\frac{\Delta\boldsymbol{R}}{\boldsymbol{R}} = \frac{\Delta\boldsymbol{a}}{\boldsymbol{a}} + \frac{\Delta\boldsymbol{b}}{\boldsymbol{b}}$$

The RULE for combining uncertainties is given in terms of fractional uncertainties, $\Delta x/_{x}$. It is simply that each factor contributes equally to the fractional uncertainty of the result.

Example: To calculate the acceleration of an object travelling the distance d in time t, we use the relationship: $a = 2\, d\, t^{-2}$. Suppose d and t have uncertainties Δd and Δt, what is the resulting uncertainty in a, Δa?

Note that t is raised to the second power, so that Δt = t counts twice. Note also that the numerical factor is the absolute value of the exponent. Being in the denominator counts the same as in the numerator. The result is that

$$\frac{\Delta \boldsymbol{a}}{\boldsymbol{a}} = \frac{\Delta \boldsymbol{d}}{\boldsymbol{d}} + 2\frac{\Delta \boldsymbol{t}}{\boldsymbol{t}}$$

Examination of the individual terms often indicates which measurements contribute the most to the uncertainty of the result. This shows us where more care or a more sensitive measuring instrument is needed.

Example: If d = 100 cm, Δd = 1 cm, t = 2:4 s and Δt = 0:2 s,

then Δd/d = (1cm) / (100cm) = 0.01 = 1%

and 2Δt/t = 2(0.2s)/(2.4s) = 0:17 = 17%.

Clearly the second term controls the uncertainty of the result.

Finally, Δa/a = 18%. (As you see, fractional uncertainties are most compactly expressed as percentages, and since they are estimates, we round them to one or two meaningful digits.) Calculating the value of a itself (2x100 x 2.4^{-2}), the calculator will display **34.7222222**. However, it is clear that with Δa/a = 18% meaning Δa ≈ 6 cm s^{-2} , most of those digits are meaningless. Our result should be rounded to 35 cms^{-2} with an uncertainty of 6 cm s^{-2}

In recording data and calculations we should have a sense of the uncertainty in our values and not write figures that are not significant. Writing an excessive number of digits is incorrect as it indicates an uncertainty only in the last decimal place written.

3. General rule for significant figures

- Non zero digits or **zeros between a number** are significant

Example:	999	- (three significant figures)
	1.432	- (four significant figures)
	2032	- (four significant figures)

- For decimals, **zeros to the left** of the first non-zero digit are not significant

  Example: 0.000095 -(two significant figures)

  Can be written as $\mathbf{9.5 \times 10^{-5}}$

- For decimals, **zeros to the right** of the first non-zero digit are not significant

  Example : 2.00 -(two significant figures)

  0.050 -(two significant figures)

  can be written as $5.0 \times \mathbf{10^{-2}}$

4. Reporting Uncertainties:

There are two methods for reporting a value V, and its uncertainty ΔV.

A. The technical form is (V ±ΔV) units.

Example: A measurement of 7.35 cm with an uncertainty of 0.02 cm would be written as (7.35 ± 0.02) cm.

Note the use of parentheses to apply the unit to both parts.

B. Commonly, only the significant figures are reported, without an explicit uncertainty. This implies that the uncertainty is 1 in the last decimal place.

Example: Reporting a result of 7.35 cm implies ±0.01 cm. Note that writing 7.352786 cm when the uncertainty is really 0.01 cm is wrong.

C. A special case arises when we have a situation like 1500±100. Scientific notation allows use of a simplified form, reporting the result as $1.5 \text{ x}10^3$.

In the case of a much smaller uncertainty, 1500±1, we report the result as $1.500 \text{ x}10^3$, showing that the zeros on the right are meaningful.

5. Additional Remarks:

- In the technical literature, the uncertainty also called the error.
- When measured values are in disagreement with standard values, physicists generally look for mistakes (blunders), re-examining their equipment and procedures. Sometimes a single measurement is clearly very different from the others in a set, such as reading the wrong scale on a clock for a single timing. Those values can be ignored, but NOT erased. A note should be written next to any value that is ignored. Given the limited time we will have, it will not always be possible to find a specific cause for disagreement. However, it is useful to calculate at least a preliminary result while still in the laboratory, so that you have some chance to find mistakes.

- In adding the absolute values of the fractional uncertainties, we overestimate the total uncertainty since the uncertainties can be either positive or negative. The correct statistical rule is to add the fractional uncertainties in quadrature, i.e.
$$\left(\frac{\Delta Y}{Y}\right)^2 = \left(\frac{\Delta a}{a}\right)^2 + \left(\frac{\Delta b}{b}\right)^2$$
- The professional method of measuring variation is to use the Standard-Deviation of many repeated measurements. This is the square root of the total squared deviations from the mean, divided by the square root of the number of repetitions. It is also called the Root- Mean-Square error (rms).
- Measurements and the quantities calculated from them usually have units. Where values are tabulated, the units may be written once as part of the label for that column The units used must appear in order to avoid confusion. There is a big difference between 15 mm, 15 cm and 15 m.

6. Graphical Representation of Data:

Graphs are an important technique for presenting scientific data. Graphs can be used to suggest physical relationships, compare relationships with data, and determine parameters such as the slope of a straight line. There is a specific sequence of steps to follow in preparing a graph. (See Figure 1)

1. Arrange the data to be plotted in a table.
2. Decide which quantity is to be plotted on the x-axis (the abscissa), usually the independent variable, and which on the y-axis (the ordinate), usually the dependent variable.
3. Decide whether or not the origin is to appear on the graph. Some uses of graphs require the origin to appear, even though it is not actually part of the data, for example, if an intercept is to be determined.
4. 4. Choose a scale for each axis, that is, how many units on each axis represent a convenient number of the units of the variable represented on that axis. (Example: 5 divisions = 25 cm). Scales should be chosen so that the data span almost all of the graph paper, and also make it easy to locate arbitrary quantities on the graph. (Example: 5 divisions = 23 cm is a poor choice.) Label the major divisions on each axis.

5. Write a label in the margin next to each axis which indicates the quantity being represented and its units. Write a label in the margin at the top of the graph that indicates the nature of the graph, and the date the data were collected.
6. (Example: Plot each point. The recommended style is a dot surrounded by a small circle. A small cross or plus sign may also be used.
7. Draw a smooth curve that comes reasonably close to all of the points. Whenever possible we plot the data or simple functions of the data so that a straight line is expected. A transparent ruler or the edge of a clear plastic sheet can be used to "eyeball" a reasonable fitting straight line, with equal numbers of points on each side of the line. Draw a single line all the way across the page. Do not simply connect the dots

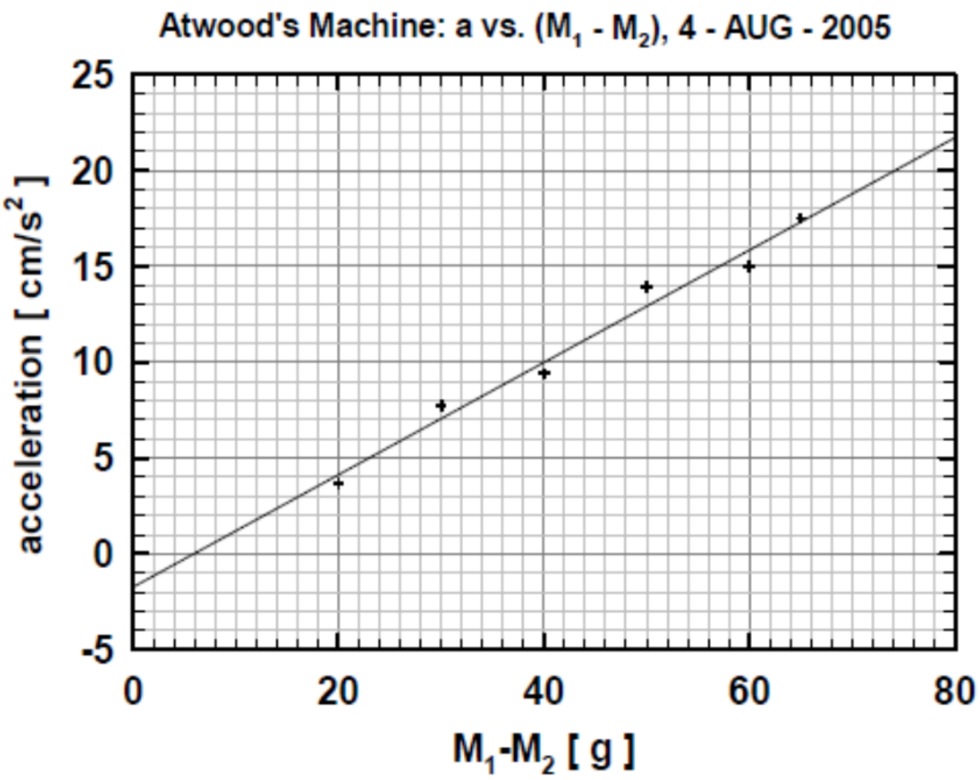


Figure 2: Example graph

"Log" PAPERS and SCALES: Semi-log and log-log papers and scales are used quantitatively to show relations between quantities when theory predicts exponential or power law behaviour. They are also used qualitatively to display data that extends over a very large range of the variables. When a number is plotted on a log scale its position represents the log of that number and the bother of looking up many logs is avoided.

Therefore, when plotting on a "log" scale you must use the printed numbers, multiplying successive "decades" by powers of 10.

For example, you cannot arbitrarily change " 1 2 3 4 56..." into "3 4 5 6 78...". Care in plotting is necessary, as the value of intermediate intervals keeps changing. For ease of reading the graph you should supply the decimal point or powers of 10, so that a typical "x" scale would read: " .1 .2 .3 .4 .6 .8 1 2 3 4 6 8 10 20 30 40 60 .. ". Note that there is no "0" on a log scale (because this would correspond to a position of $-\infty$). Semi-log paper is useful if the theoretical relation is $H = H_0 e^{bt}$. Since $\ln H = \ln H_0 + bt$, a straight line with slope "b" will be obtained when ($\ln H$) is plotted against t.

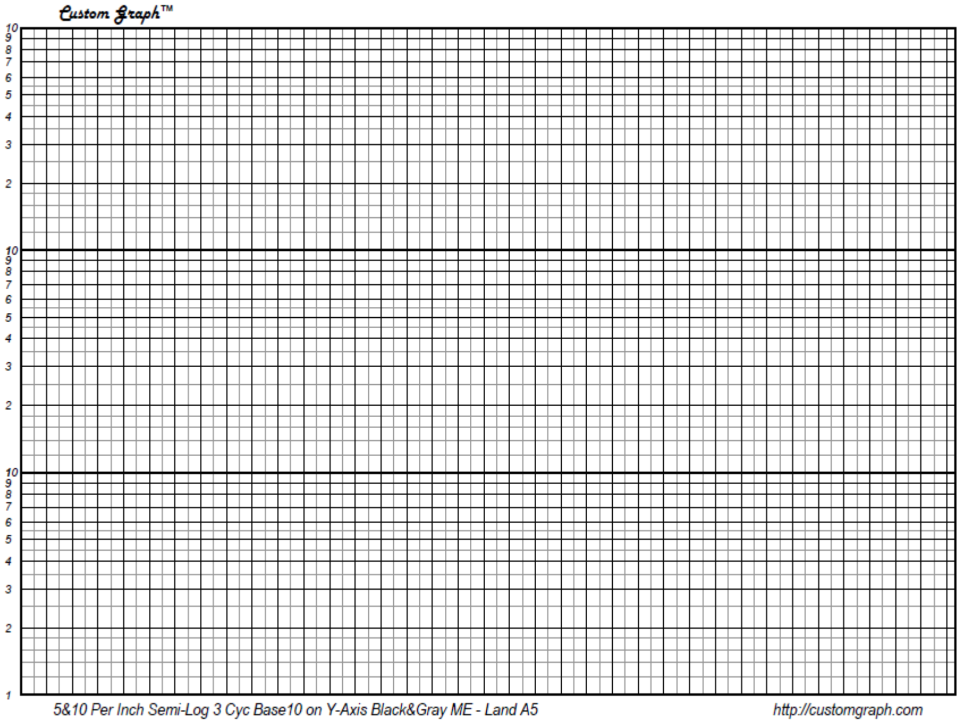


Figure 3 Example of a semi log plot

Exercise 1 : The leaky water bucket":

In an experiment, a student has recorded the times at which the level in a cylindrical water "bucket" passed each centimetre mark on the side of the cylinder. Analyse the data shown here.

Height (cm.)	time (Sec.)
18	0
17	5
16	10
15	14
14	19
13	25
12	31
11	37
10	43
9	51
8	60
7	110
6	121
5	134
4	150
3	211
2	246
1	345

Exercise 2: **:** Light intensity vs distance from a small source

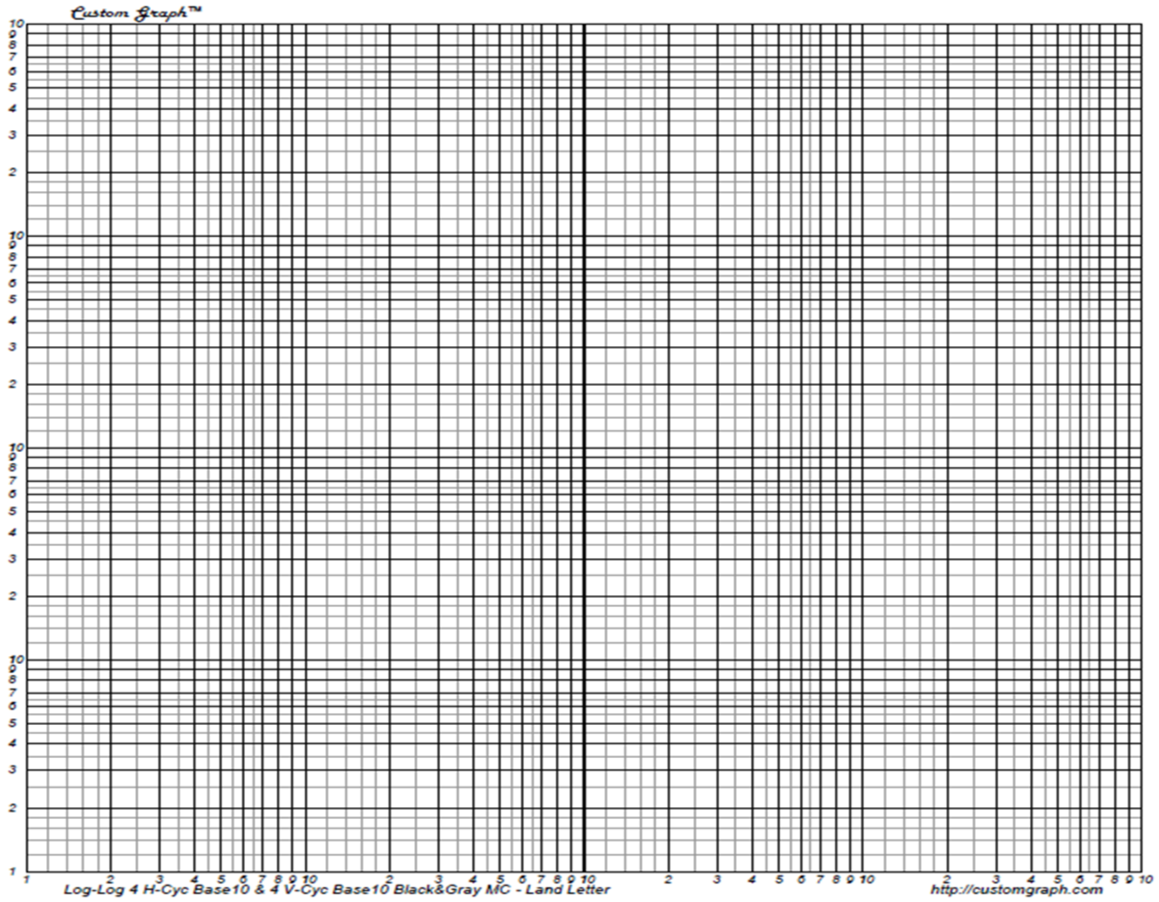


Figure 4 Example of log-log paper

The measurements of the light intensity (brightness) at a detector that is moved farther and farther from the light source is performed. One has to analyze the data. He knows that light from a "point" source should obey the "inverse square law," a power law and wants to evaluate using log-log paper.

Distance (cm.) ±0.2 cm.	5	10	15	20	30	40	60	80
Intensity (ft-cndls.) ±5%	60	16	7.4	4.3	2.1	1.3	0.74	0.55

VERNIER CALIPERS

AIM

To measure the dimensions of the given objects such as

(i) Thickness of a glass plate

(ii) Volume of a cylinder

(iii) Volume of a sphere

APPARATUS

Vernier Calipers, glass plate, cylinder and sphere

DESCRIPTION

As shown in figure 1, The Vernier Calipers consist of a long rigid rectangular steel strip called the main scale (M.S) with a jaw (A) fixed at one end perpendicular to its length. The main scale is graduated both in centimeters and inches. The second jaw (B) carrying a vernier scale and capable of moving along the main scale can be fixed to any position by means of a screw cap S. The vernier scale i s divided into 10 divisions, which is equivalent to 9 main scale divisions (M.S.D). So the value of 1 vernier scale division is equal to $\frac{9}{10}$ M.S.D. The value of 1 M.S.D. is 0.1 cm

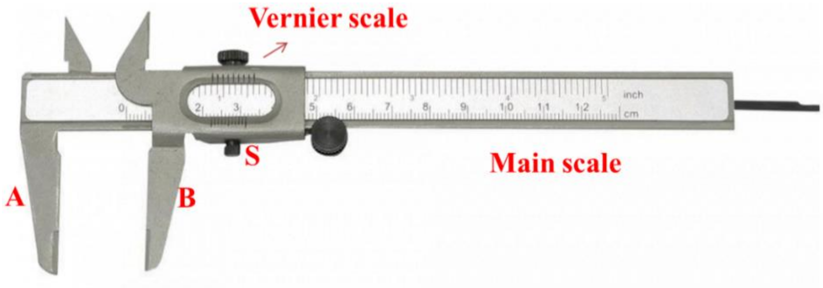


Figure 1 vernier calipers

PROCEDURE

1. To find the Least Count (LC) of the vernier calipers (see Figure 2)

It is the smallest length that can be measured accurately by the vernier calipers and is measured as the difference between one main scale division and one vernier scale division

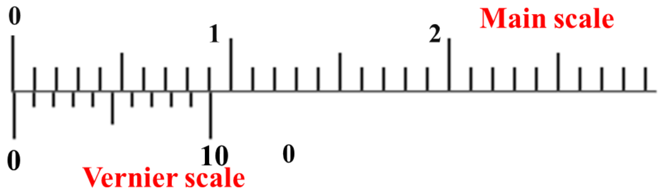


Figure 2 Vernier scale and main scale

Vernier formula:

N vernier scale divisions = (N-1) Main scale divisions

Value of 1 M.S.D = 0.1cm

No of divisions on the vernier scale = 10 divisions.

Therefore, $10\ V.S.D = 9\ M.S.D$

$$1\ V.S.D = \frac{9}{10}\ M.S.D = \frac{9}{10} \times 0.1\ cm = \frac{0.9}{10}\ cm$$

$$Least\ \ Count\ (L.C) = 1\ M.S.D - 1\ V.S.D$$

$$= 0.1cm - \frac{0.9}{10}\ cm$$

$$= 0.01cm$$

2. To find the Zero Correction (ZC)

Before taking the readings with the vernier calipers, we must note the zero error of the vernier calipers. When the two jaws of the vernier calipers are pressed together, if the zero of the vernier scale coincides with the zero of the main scale the instrument has no error, otherwise there is a zero error. The zero error is positive if the vernier zero is after the main scale zero. The zero error is negative when the vernier zero is before the main scale zero. In general, the zero error is negligible in the case of vernier calipers and so zero error can be considered to be nil.

3. To find the thickness of the given object:

The given object is firmly gripped between the jaws, taking care not to press it too hard. The main scale reading and the vernier coincidence are noted. The main scale reading is the reading on the main scale that is just before the vernier zero. The vernier scale coincidence is found by noting the vernier division that coincides with any one of the main scale. Then the vernier scale reading is found by multiplying the vernier coincidence with the least count. The observations are repeated for various positions of the object.

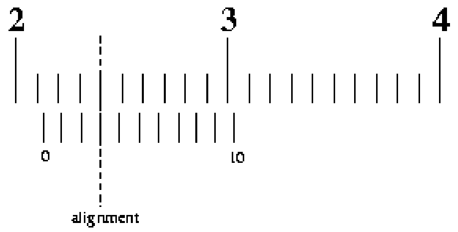


Figure 3 Vernier Calipers readings

Example:

Vernier Calipers readings: (See Figure 3)

LC = 0.01cm

S.No	**M.S.R cm**	**V.C**	**Total Reading = M.S.R+(V.Cx L.C))**
1	2.1	4	2.34
2			
3			
4			
5			

Average thickness of the glass plate = cm

RESULT

The thickness of the glass plate = cm

SCREW GUAGE

AIM

To measure the dimensions of the given objects such as

(i) Thickness of a glass plate

(ii) Volume of a cylinder

(iii) Volume of a sphere

APPARATUS

Vernier Calipers, glass plate, cylinder and sphere

DESCRIPTION

It is based upon the principle of a screw. It consists of a U-shaped metal frame. One end of which carries a fixed stud whereas the other end is attached to a cylindrical tube as shown in Figure 1. A scale graduated in millimetres is marked on the cylindrical tube along its length. It is called Pitch scale

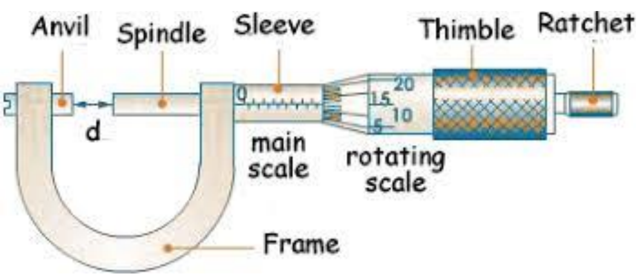


Figure 2 Screw guage

The screw carries a head which has a beveled edge. The edge is divided into 100 equal divisions. It is called the Head scale H.S. When the head is rotated, the head scale moves on the pitch scale.

PROCEDURE

To find the least count (LC) of the screw gauge

Least count of a screw gauge is the distance through which the screw tip moves when the screw is rotated through one division on the head scale. To find the pitch, the head or the screw is given say 5 rotations and the distance moved by the head scale on the pitch scale is noted. Then by using the above formula, the least count of the screw gauge is calculated.

$$Pitch\ of\ the\ screw = \frac{Distance\ moved}{\#\ of\ rotations\ made} = \frac{5mm}{5} = 1mm$$

$$Least\ count(L.C) = \frac{Pitch\ of\ the\ Screw}{\#\ of\ Head\ Scale\ Divisions} = \frac{1mm}{100} = 0.01mm = 0.001cm$$

To find the zero correction (ZC)

i) Nil error

If the zero of the head scale coincides with the zero of the pitch scale and also lies on the base line (B.L), the instrument has no zero error and hence there is no zero correction (See Figure 2)

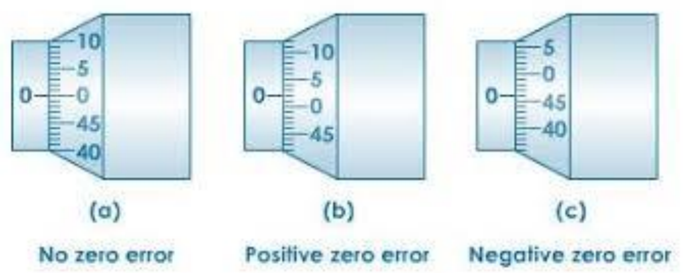


Figure 2 Zero error of Screw gauge

ii) Positive zero error

If the zero of the head scale lies below the base line (B.L) of the pitch scale then the zero error is positive and zero correction is negative. The division on the head scale, which coincides with the base line of pitch scale, is noted. The division multiplied by the least count gives the value of the positive zero error. This error is to be subtracted from the observed reading i.e. the zero correction is negative (See Figure 2).

iii) Negative zero error

If the zero of head scale lies above the base line (B.L) of the pitch scale, then the zero error is negative and zero correction is positive. The division on the head scale which coincides on the base line of pitch scale is noted. This value is subtracted from the total head scale divisions. This division multiplied by the least count gives the value of the negative error. This error is to be added to the observed reading i.e. zero correction is positive (See Figure 2).

To find the thickness of the glass plate

The glass plate is gently gripped between the faces A and B. The pitch scale reading and the head scale coincidence are noted. The readings are tabulated.

Pitch Scale Reading (P.S.R)

Number of pitch scale division just in front of the head scale fully completed is noted. It is measured in millimetre.

Head Scale Coincidence (H.S.C)

Coincidence of head scale division on the base line of the pitch scale is also noted.

Example:

Screw gauge readings:

LC = 0:01 mm Zero error = -3 divisions correction (Z.C.) = +3 divisions

S.No.	P.S.R	H.S.R		T.R= P.S.R+(H. S. R x L.C)
		Observed	Corrected	
1				
2				
3				
4				
5				

Mean thickness of the glass plate =

RESULT

EXPERIMENT 2

DIFFRACTION GRATING

AIM

To determine the wavelengths of different colours of the spectrum of mercury source, using diffraction grating by normal incident method

APPARATUS

Spectrometer, diffraction grating, mercury vapour lamp and magnifier torch

.

WORKING FORMULA

$$\lambda = \frac{\sin\theta}{nN}\ nm$$

Where, **θ** is the angle of diffraction in degree

N is the number of lines per metre in the grating in lines/m

n is the order of the spectrum

DIAGRAM

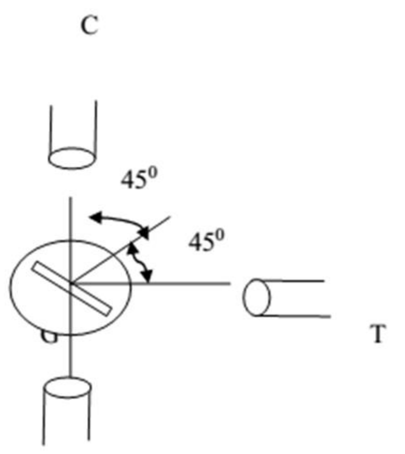


Figure 1 Grating set for normal to the incident light

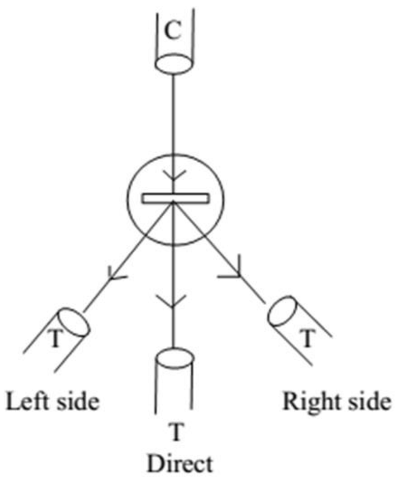


Figure 2 Diffracted images

PROCEDURE

1. Focus the telescope to a distant object for receiving parallel light.
2. Keep the collimator aperture to the source of light. Adjust the width of the aperture to get a narrow beam of light.
3. Turn the telescope towards the collimator. Observe the vertical image of the collimator in the telescope. Adjust the focus of the collimator to get a sharp image.
4. Adjust the eye-piece of the telescope to coincide the cross-wires to the image of the collimator.
5. Lock the collimator and the telescope. Note down the telescope reading.
6. Release the telescope and turn it so that the reading on the scale is altered exactly by 90^0 lock the telescope again.
7. Place the grating, G on its holder so that the normal to its plane is approximately half-way between the telescope and the collimator.
8. Seeing through the telescope, adjust the grating holder slowly until the reflected light from the grating is coinciding with the cross wires.
9. Keeping the telescope locked, release the circular scale. Turn the circular scale exactly by 45^0 such that the grating is normal to the incident light from the collimator. Lock the circular scale again.
10. Release the telescope, and turn it to see the direct image once again.
11. Turn the telescope slowly to L.H.S. to observe the first ordered spectrum.
12. Adjust the telescope and coincide the cross wire with a particular colour of the spectrum. Use fine adjustment screw, if required. Note down the telescope reading.
13. Repeat step (12) for each of the colour in the spectrum.
14. After recording the spectrum on L.H.S, turn the telescope to the spectrum on R.H.S.
15. Repeat steps (12) & (13) for corresponding colours on the R.H.S
16. The difference between the readings of the telescope for corresponding colour on L.H.S &R.H.S gives the twice the angle of diffraction
17. Enter the readings in a tabular form.

OBSERVATIONS& TABULAR FORM:

1. Value of 1 M.S.D = minutes
2. No. of divisions on the vernier scale =
3. Least count = minutes
4. Number of lines per cm, N =
5. Order of the spectrum, N =

S.No	Colour	Telescope readings in deg & min						$\theta = \theta_1 \sim \theta_2$	$\lambda = \frac{\sin\theta}{nN}$
		L.H.S			R.H.S				
		M.S.R	V.C	θ_1=M.S.R + (V.C×L.C)	M.S.R	V.C	θ_2=M.S.R + (V.C×L.C)		

PRECAUTIONS

1. The image of the collimator must be narrow and set vertical.
2. Note down the vernier coincidence accurately.
3. When the cross-wire coincides to the spectral line, lock the telescope and use fine-adjustment screw.
4. Hold the grating at its edges only. Avoid finger prints to form on the surface of the grating.

RESULT

EXPERIMENT 3

DIFFRACTION GRATING

AIM

To determine the wavelength of the laser light using diffraction grating

APPAATUS

Diffraction grating, Semiconductor laser, optical bench and screen or scale arrangement

WORKING FORMULA

Wavelength of a laser light

$$\lambda = \frac{\sin\theta}{nN}\ nm$$

Where, $\theta = \tan^{-1}\left(X_n/l\right)$ is the angle of diffraction in degree

N is the number of lines per metre in the grating in lines/m

n is the order of the spectrum

DIAGRAM

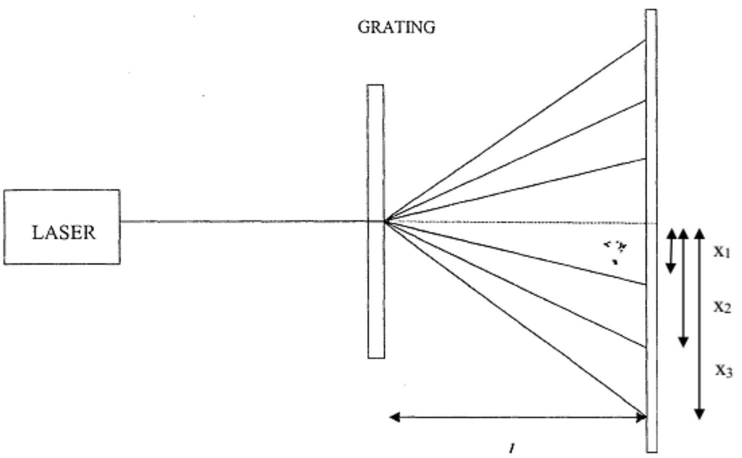


Fig. 1. Experimental Setup

PROCEDURE

1. The laser is mounted on its saddle on the optical bench.
2. The grating is mounted on an upright next to laser. The screen or scale arrangement is placed next to the grating as shown in Figure 1.
3. The laser is switched on. The relative orientation of laser with respect to grating is adjusted such that spectral spots are observed on the screen (graph sheet).
4. The screen is moved towards and away from the grating till at least three (for 300lines/mm) spots are clearly seen on the scale on the either side of the central spot.
5. The central maximum and other maxima corresponding to different orders of the spectrum on either side of the central maximum are identified.
6. The graph sheet is again adjusted in such a way that the central spot coincides with the zero of the coordinate axis.
7. Now the distances ($\mathbf{X}_n$) of the spots corresponding to first order, second order etc. on either side of central maximum are noted.
8. The distance between the grating and the scale (l) is measured. The readings are tabulated.
9. The experiment is repeated for at least three l values (15cm, 20cm &25cm). The value of $\mathbf{X}_n$ is calculated for each case using the formula $\theta = \tan^{-1}(\mathbf{X}_n / l)$.
10. Knowing the values of θ , n & N, the wavelength of laser light can be calculated using the formula $\lambda = \sin\theta / n N$

OBSERVATIONS

Distance of the spot from the central maximum (X_n) = m

Perpendicular distance between grating & the scale (l) = m

Number of lines per metre in the grating (N) = lines/m

S. No.	Order n	l cm	x_n cm			$\theta = \tan^{-1}(x_n/l)$	Sin θ	$\lambda = \sin\theta / nN$
			LHS	RHS	Mean			
1	1							
2	2							
3	3							
4	1							
5	2							
6	3							
7	1							
8	2							
9	3							

Angle of diffraction, $\theta = \tan^{-1}(X_n / l)$ =

Wavelength of laser light, $\lambda = \sin\theta / nN$

PRECAUTIONS

1. Never look directly into the laser beam. Laser light has a high intensity and can also be easily focused. A direct shot of the laser beam on your eye will be focused by your cornea onto a small spot on your retina and can burn or possibly detach the retina.
2. Never hold a reflecting object by hand in front of the laser beam. This prevents the possibility of accidentally shining the light into your eyes.
3. Keep your head above the plane of the laser beam.
4. Whenever the light strikes an object, there will be a reflection. At times the reflections can be almost as strong as the incident beam. Know where the reflections are and block them if necessary.
5. Switch off the laser when not taking data

RESULT

EXPERIMENT 4

NUMERICAL APERTURE

Aim: To determine the acceptance angle and numerical aperture of an optical fiber.

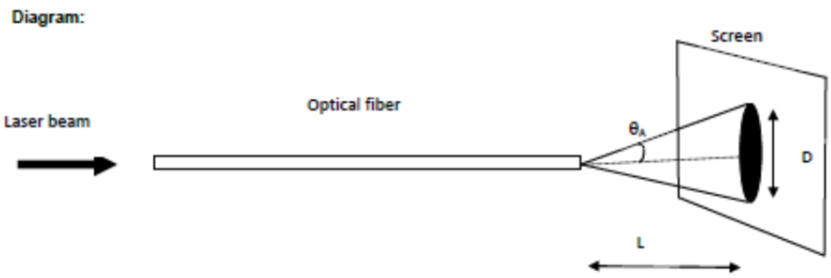
Apparatus: Single strand plastic optical fibers of different core diameter/length, laser source and screen.

Formula:

Numerical aperture represents the light gathering capacity of an optical fiber.
It is given by NA = $\sin\theta_o = \sqrt{n_1^2 - n_2^2}$
Here n_o is the refractive index of the medium from which light is entering.
θ_o is the angle of acceptance.
n_1 is the refractive index of the core.
n_2 is the refractive index of cladding.

Procedure:

1. Connect the fiber to the Laser source.
2. Take the other end of the fiber and project the light output on to the screen to obtain a bright circular spot.
3. Determine the diameter D of the bright spot and the distance L from the fiber end to the screen.
4. Calculate the acceptance angle using the formula $\theta_o = \tan^{-1}\left(\frac{D}{2L}\right)$
5. Numerical aperture is given by NA = $\sin\theta_0$.
6. Repeat this procedure for at least four other values of distance L and calculate the acceptance angle and numerical aperture in each case.
7. Finally take the average of the four numerical aperture values.



Tabular Column:

Trial No.	L (cm)	D (cm)		Average D (cm)	Angle of Acceptance $\theta_o = \tan^{-1}\left(\frac{D}{2L}\right)$	Numerical aperture NA = $\sin\theta_o$
		D_H	D_V			

Average Acceptance angle (**θ_o**) = **………………..**

Average Numerical aperture (NA) = ………………………….

<u>Result:</u> The Numerical aperture & acceptance angle for the given optical fiber is found to be ………….. and …………… respectively.

EXPERIMENT 5

CHARACTERISTICS OF A ZENER DIODE

AIM

(i) To study the V-I characteristics of a Zener diode in forward bias and reverse bias and to obtain the break down voltage

(ii) To determine the dynamic resistance of a Zener diode in reverse bias condition.

APPARATUS

Zener diode, Regulated power supply, Voltmeters, Ammeters and connecting wires

WORKING FORMULA

Dynamic resistance

$$R_z = \frac{\Delta V}{\Delta I}, \qquad \Omega$$

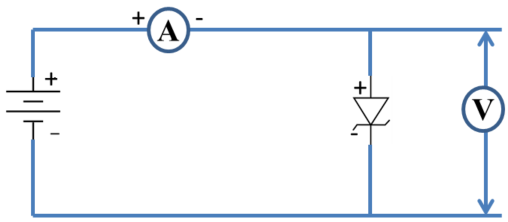
Here, ΔV = change in voltage in V

ΔI = change in current in mA

CIRCUIT CONNECTIONS

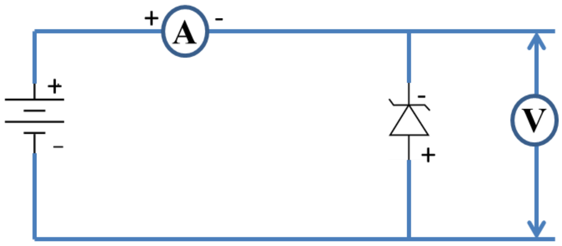
Forward bias:

When the P-side of the diode is connected is connected to +ve terminal of the battery and N-side to -ve terminal of the battery then the arrangement is called forward bias.

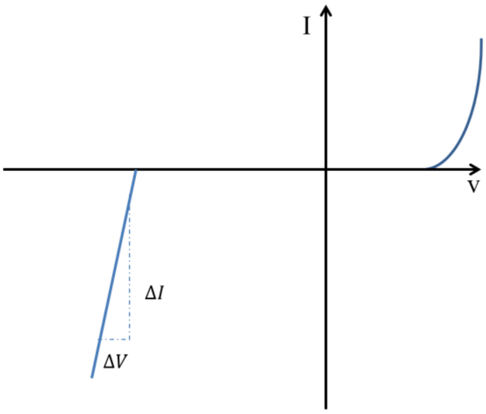


Reverse bias:

When the p -side of the diode is connected is connected to -ve terminal of the battery and n-side to +ve terminal of the battery then the arrangement is called reverse bias.



MODEL GRAPH



PROCEDURE

Forward bias

1. Connect the circuit as per the forward bias circuit diagram.
2. Vary the power supply in such a way that the readings are taken in multiple steps (say 0.1V)
3. Note down the corresponding ammeter readings.
4. Plot the graph: V_f verses I_f.
5. Find the dynamic resistance R = $\Delta V/\Delta I$

Reverse bias

1. Connect the circuit as per the reverse bias circuit diagram.
2. Vary the power supply in such a way that the readings are taken in multiple steps (say 0.1V)
3. Note down the corresponding ammeter readings.
4. Plot the graph: V_R verses I_R.
5. Find the dynamic resistance R_Z = $\Delta V/\Delta I$

OBSERVATIONS

Forward bias

S.No	Voltage (V)	Current (A)

Reverse bias

S.No	Voltage (V)	Current (A)

PRECAUTIONS

1. All connections should be neat, clean and tight.
2. The Zener diode should be connected in reverse bias.
3. Voltmeter and microammeter of appropriate least count and ranges are to be chosen.
4. Zero error if any in the voltmeter or milliammeter should kept nil.

RESULT

EXPERIMENT 6

CHARACTERISTICS OF p-n JUNCTION DIODE

AIM

To study the V-I characteristics of a pn junction in forward bias and reverse bias and to obtain the dynamic resistance

APPARATUS

PN junction diode, Regulated power supply, Voltmeters, Ammeters and connecting wires

WORKING FORMULA

(i) Dynamic forward resistance

$$R_f = \frac{\Delta V_f}{\Delta I_f}$$

Here, ΔV_f = change in voltage in forward bias (V)

ΔI_f = change in current in forward bias (mA)

(ii) Dynamic reverse resistance

$$R_R = \frac{\Delta V_R}{\Delta I_R}$$

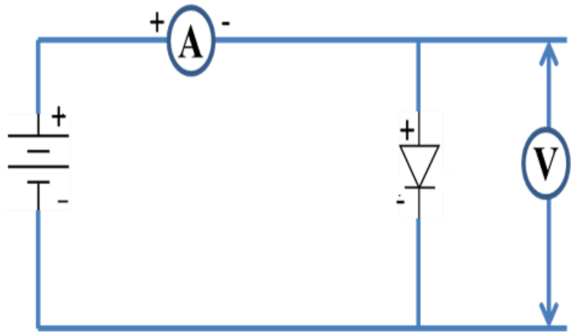
Here, ΔV_R = change in voltage in forward bias (V)

ΔI_R = change in current in forward bias (μA)

CIRCUIT CONNECTIONS

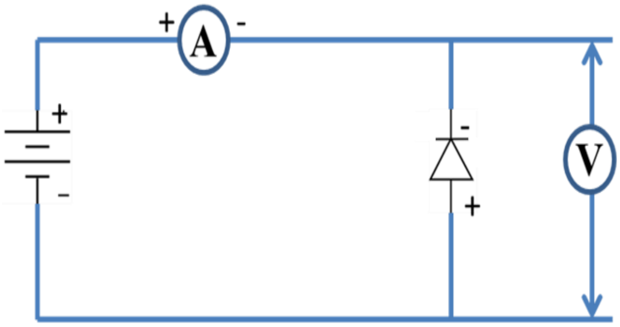
Forward bias:

When the p-side of the diode is connected is connected to positive terminal of the battery and n-side to negative terminal of the battery then the arrangement is called forward bias.

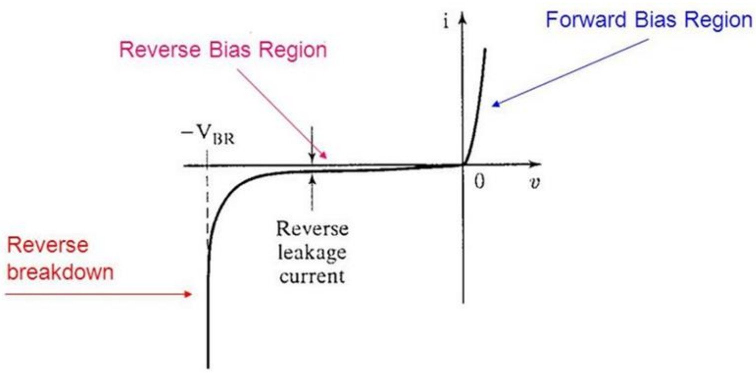


Reverse bias:

When the p -side of the diode is connected is connected to -ve terminal of the battery and n-side to +ve terminal of the battery then the arrangement is called reverse bias.



MODEL GRAPH



PROCEDURE

Forward bias

- Connect the circuit as per the forward bias circuit diagram.
- Vary the power supply in such a way that the readings are taken in multiple steps (say 0.1V)
- Note down the corresponding ammeter readings.
- Plot the graph: V_f verses I_f.

Reverse bias

- Connect the circuit as per the reverse bias circuit diagram.
- Vary the power supply in such a way that the readings are taken in multiple steps (say 0.1V)
- Note down the corresponding ammeter readings.
- Plot the graph: V_R verses I_R.
- Determine reverse breakdown voltage (V_R)

OBSERVATIONS

Forward bias

S.No	Applied Voltage (V)	Current in the circuit (mA)

Reverse bias

S.No	Applied Voltage (V)	Current in the circuit (mA)

PRECAUTIONS

1. All connections should be neat, clean and tight.
2. The pn junction diode should be connected in reverse bias.
3. Voltmeter and microammeter of appropriate least count and ranges are to be chosen.
4. Zero error if any in the voltmeter or milliammeter should kept nil.

RESULT

(i) Dynamic forward resistance of given pn junction diode =

(ii) Dynamic reverse resistance of given pn junction diode =

EXPERIMENT 7

CHARACTERISTICS OF THERMISTOR

AIM

To verify the resistance temperature characteristics of given thermistor

APPARATUS

Thermistor, thermometer, Multimeter, oven

WORKING FORMULA

The dependence of the resistance on temperature can be approximated by following equation

$$R = R_0\, exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

Where, R is the resistance of thermistor at the temperature T (in K)

R_0 is the resistance at given temperature T_0 (so called base temperature)

β is the material specific-constant

and

$$\beta = \frac{\log R - \log R_0}{\frac{1}{T} - \frac{1}{T_0}}$$

Also the temperature coefficient of resistance

$$\alpha = \frac{1}{R}\frac{dR}{dT} = -\frac{\beta}{T^2}, \quad K^{-1}$$

DIAGRAM

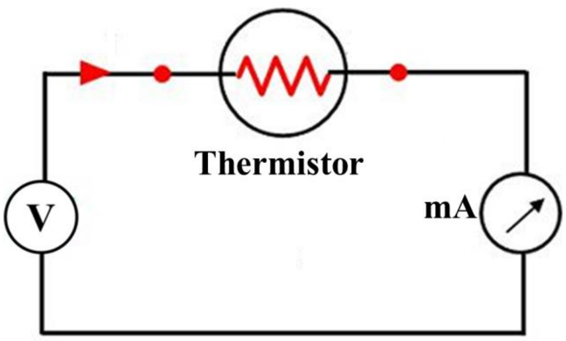


Figure 1 Thermistor circuit

MODEL GRAPH

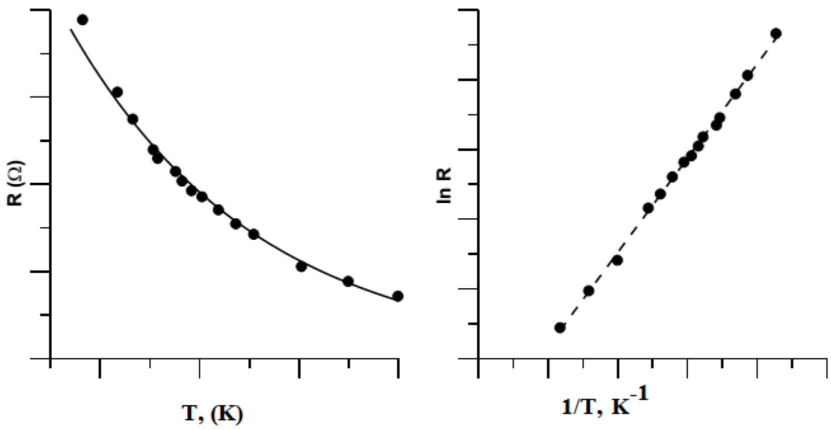


Figure 2, Temperature dependence of resistance of a thermistor

PROCEDURE

1. Connect the circuit according the diagram in Figure 1
2. Keeping the voltage applied to the thermistor is constant say (2Vor 4V)
3. Put the thermometer in the oven, turn on the oven, and keep the oven switch in High
4. Supply heat to the oven and with the change of temperature not the corresponding ammeter readings.
5. Convert the ammeter reading in to resistance using the formula V=IR (Ohm's law)
6. Repeat the experiment for 10 to 15 temperatures and the readings are tabulated.
7. Plots a graph between the resistance and a temperature as shown in figure 2

OBSERVATIONS

Voltage applied to the thermistor = V

S.No	Temperature of the oven		Current through thermistor (I mA)	Resistance $R = \frac{V}{I}, \Omega$	$\frac{1}{T} - \frac{1}{T_0}$	$\log R - \log R_0$	β	$\alpha = -\frac{\beta}{T^2}, K^{-1}$
	T, (^{0}C)	T, (K)						

PRECAUTIONS

1. Much current should not be sent through the thermistor.
2. Readings should be taken without parallax error.
3. Handle all equipment with care.
4. Make connections according to the circuit diagram.
5. Take the readings carefully.
6. The connections should be tight.

RESULT

EXPERIMENT 8

SOLAR CELL

AIM

To plot the V-I Characteristics of the solar cell and hence determine the fill factor.

APPRATUS

Solar cell, Load resistances, patch chords. Wooden plank with half meter scale, 100 watt lamp.

WORKING FORMULA

$$Fill\ factor = \frac{V_m \times I_m}{V_{oc} \times I_{sc}}$$

Here, V_m= voltage corresponds to maximum power output (mV)

I_m = current corresponds to maximum power output (mA)

V_{oc}= open circuit voltage (mV)

I_{sc} = short circuit current (mA)

CIRCUIT DIAGRAM

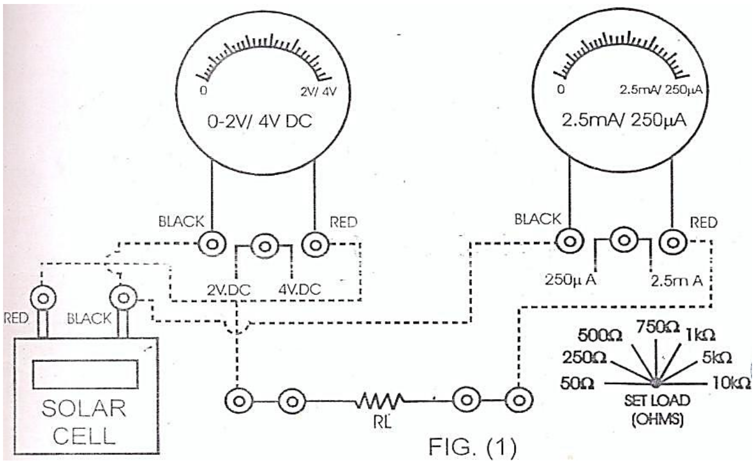


FIG. (1)

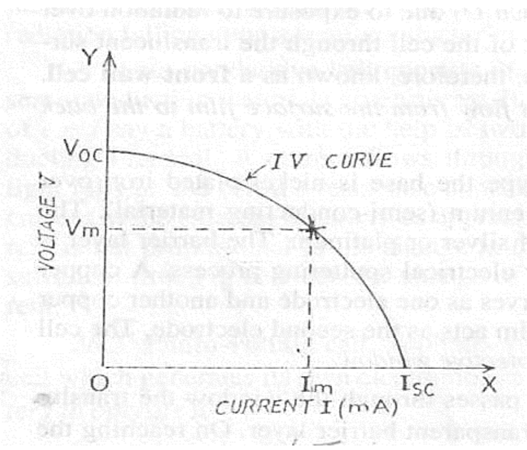
PROCEDURE

- Place the solar cell and the light source (100 watt lamp) opposite to each other on a wooden plank. Connect the circuit as shown by dotted lines through patch chords.
- Select the voltmeter range to 2V, current meter range to 250μA and load

resistance (RL) to 50Ω.

- Switch ON the lamp to expose the light on Solar Cell.
- Set the distance between solar cell and lamp in such a way that current meter shows 250 μA deflections. Note down the observation of voltage and current in Table 1.
- Vary the load resistance through band switch and note down the current and voltage readings every time in Table 1.
- Plot a graph between output voltage vs. output current by taking voltage along X-axis and current along Y-axis.

MODEL GRAPH



OBSERVATIONS

Ideal Power = $V_{OC} \times I_{SC}$ =

Maximum useful power = $V_m \times I_m$

The ratio of the maximum useful power to ideal power is called the fill factor

$$Fill\,factor = \frac{V_m \times I_m}{V_{oc} \times I_{sc}}$$

S. No	Voltage	Current	Load Resistance (RL)

PRECAUTIONS

1. The solar cell should be exposed to sun light before using it in the experiment.
2. Light from the lamp should fall normally on the cell.
3. A resistance in the cell circuit should be introduced so that the current does not exceed thesafe operating limit

RESULT

Fill factor of a given solar cell =

EXPERIMENT 9

HALL EFFECT

AIM

To determine the Hall voltage developed across the sample material.

To calculate the Hall coefficient and the carrier concentration of the sample material.

APPARATUS

Two solenoids, Constant current supply, Four probe, Digital gauss meter, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

WORKING FORMULA

Hall coeffectient

$$R_H = \frac{V_H\, t}{I\, B} \qquad where\ R_H = \frac{1}{n\, e}$$

Here, V_H = Hall voltage (mV)

t = thickness of saple (m)

I = applied current (A)

B = applied magnetic field (Tesla)

e = charge of an electron (C)

n= charge carrier density (cm^{-3})

SCHEMATIC REPRESENTATION OF HALL SETUP

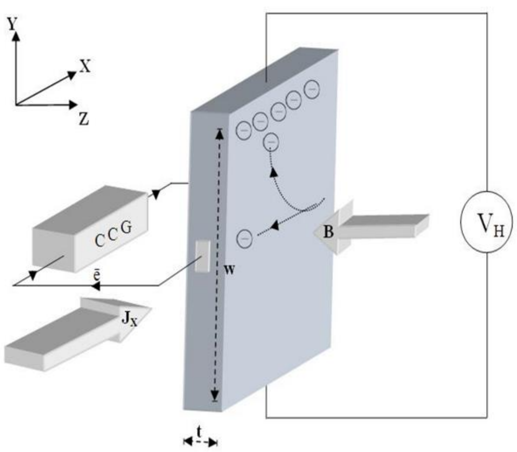


Table 1

SNo:	Current through Solenoid (A)	Magnetic field Generated (Tesla)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Table 2

Trial No:	Magnetic Field (Tesla T)	Thickness (t) m	Hall current, mA	Hall Voltage mV	R_H
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

PROCEDURE

- Connect ‘Constant current source to the solenoids.
- Four probe is connected to the Gauss meter and placed at the middle of the two solenoids.
- Switch ON the Gauss meter and Constant current source.

- Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings.
- Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
- Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator and connect red wires to milli voltmeter in the Hall Effect apparatus.
- Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids. Switch ON the constant current source.
- Carefully increase the current I and measure the corresponding Hall voltage V_H. Repeat this step for different magnetic field $\boldsymbol{B}$. calculate the Hall coefficient R_H and carrier concentration $\boldsymbol{n}$.

PRECAUTIONS

1. The magnet power supply can furnish large currents at dangerous voltage levels; do not touch exposed magnet coil contacts.
2. Large inductive voltage surges may damage the insulation. Start with controls set for zero current and gradually increase current. When turning off, smoothly decrease current to zero and then turn off.
3. Do not exceed magnet current of 10 A.
4. Do not exceed Hall probe current of 0.4 A

RESULT

Hall coefficient of the material = ...

Carrier concentration of the material =.......................... m^{-3}

EXPERIMENT 10

PLANCK'S CONSTANT DETERMINATION

AIM

To determine the Planck's constant using photocell.

APPARATUS

Photo emissive cell, regulated DC power supply, filters, light source, digital voltmeter and digital micro ammeter.

WORKING FORMULA

Planck's constant

$$h = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c\ (\lambda_1 - \lambda_2)},\quad Joule - second$$

where e = charge of electron = $1.6\ X\ 10^{-19} C$

c = speed of light = $3\ X\ 10^{8}\ m/s$

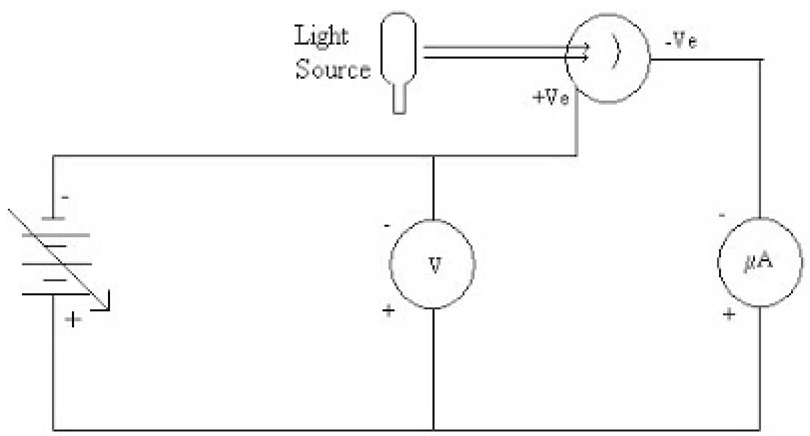
λ_1 and λ_2 are wavelength of the monochromatic light

V_1 and V_2 are stopping potentials

Percentage Error:

$$percentaage\ error = \frac{standard\ value \sim experimental\ value}{standard\ value}\ X\ 100$$

CIRCUIT CONNECTIONS



PROCEDURE

1. Connections are made as shown in the figure.
2. Switch ON the light and allowed to fall on the photo cell.
3. Adjust the distance between the source and photocell such that the flow of electrons are sufficiently high.
4. A suitable filter of known wavelength is placed in the path of the light.
5. Note down the reading corresponding to the zero anode potential is observed in the microammeter. A small negative potential is applied which is gradually increased in small steps till the microammeter reading comes to zero.
6. This voltage is called stopping potential of the corresponding wavelength.
7. The experiment is repeated with other filters and corresponding stopping potentials are noted.

OBSERVATIONS

S.No	Filter	Wavelength (nm)	Frequency (Hz)	Stopping potential (V)
1	Orange	612		
2	Blue	474		
3	Green	527		
4	Red	650		

RESULT

The experimental value of Planck's constant = ________________________

Percentage error = _____________________________