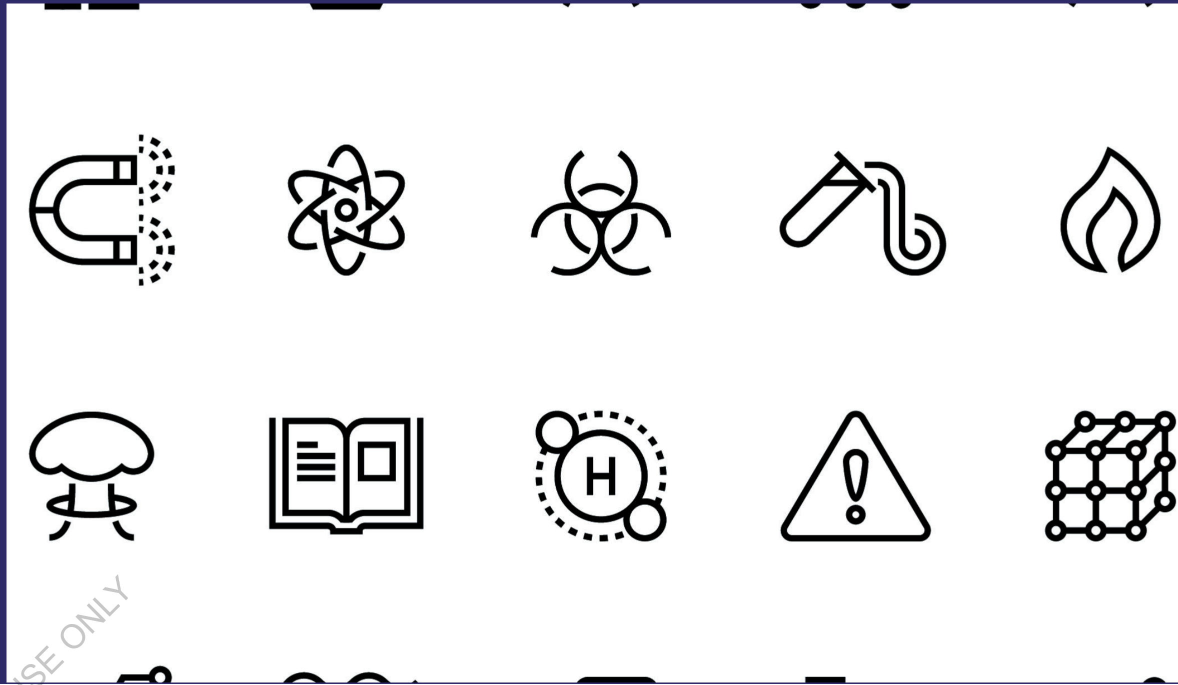
All the experiments are described in a uniform format - list of objectives, an introduction, necessary elementary theory, detailed stepwise procedure, recording of observations, method of plotting relevant graphs, method of performing calculations from recorded data and reporting the result with errors, conclusions, precautions and review questions. Necessary diagrams, labeled photographs of the experimental set-up and illustrative graphs are included. The student is expected to read each experiment thoroughly prior to its actual performance.



Sanni Kaptel was born in Vaso, Gujarat on August 10, 1991. He completed his graduate studies recently with a Ph.D. from the Charotar University of Science and Technology (CHARUSAT, India) in 2019. His current research interests are in the areas of Synthesis and characterization of semiconductor nanocomposites, nanoscience, Layered Semiconductors.

978-620-0-28047-3

Sanni Kapatel
Manan Shah

Engineering Physics Manual/Journal

Laboratory Handbook

LAP LAMBERT Academic Publishing

Sanni Kapatel
Manan Shah

Engineering Physics Manual/Journal

Sanni Kapatel
Manan Shah

Engineering Physics Manual/Journal

Laboratory Handbook

LAP LAMBERT Academic Publishing

Imprint

Cover image: www.ingimage.com

Publisher:
LAP LAMBERT Academic Publishing
is a trademark of
International Book Market Service Ltd., member of OmniScriptum Publishing Group
17 Meldrum Street, Beau Bassin 71504, Mauritius

Printed at: see last page
ISBN: 978-620-0-28047-3

ENGINERRING PHYSICS
LABORATORY MANUAL/JOURNAL

Dr. Sanni Dilipbhai Kapatel

P. D. PATEL INSTITUTE OF APPLIED SCIECNCE
CHAROTAR UNIVERSITY OF SCIENCE AND TECHNOLOGY

Changa – 388421, Dist: Anand, Gujarat, India

Dr. Manan Nareshkumar Shah

P. D. PATEL INSTITUTE OF APPLIED SCIECNCE
CHAROTAR UNIVERSITY OF SCIENCE AND TECHNOLOGY

Changa – 388421, Dist: Anand, Gujarat, India

CONTENTS

PREFACE

The manual/ journal gives necessary details to perform the experiments. Most of the experiments are designed to go hand-to-hand with the theoretical courses on Engineering Physics being taught in the first year B.Tech. (All branches) and the main objective is: **Learning Physics through Experimentations**. All the experiments are described in a uniform format - list of objectives, an introduction, necessary elementary theory, detailed stepwise procedure, recording of observations, method of plotting relevant graphs, method of performing calculations from recorded data and reporting the result with errors, conclusions, precautions and review questions. Necessary diagrams, labeled photographs of the experimental set-up and illustrative graphs are included. The student is expected to read each experiment thoroughly prior to its actual performance.

It explains all the aspects related to many experiments such as: basic underlying physical principle, details of the instruments, how to use these instruments for the desired purpose, the theoretical formalism & formulae, procedure of performing the experiment and how to calculate the desired results from the observations etc. It also gives sufficient information on how to interpret and discuss the obtained results. An appendix is included in the Manual. These provide information related to constants, formulae *etc.*

The authors and publishers of all the books which are referred while developing this manual are also acknowledged.

Dr. Sanni Kapatel **Dr. Manan Shah**

GENERAL INSTRUCTIONS FOR LABORATORY

- ❖ The objective of the laboratory is learning. The experiments are designed to illustrate phenomena in different areas of Physics and to expose you to measuring instruments. Conduct the experiments with interest and an attitude of learning.
- ❖ You need to come well prepared for the experiment.
- ❖ Read the relevant background material in your textbook, or in library references
- ❖ Work quietly and carefully (the whole purpose of experimentation is to make reliable measurements) and equally share the work with your partners.
- ❖ Be honest in recording and representing your data. Never make up readings or doctor them to get a better fit for a graph. If a particular reading appears wrong repeat the measurement carefully. In any event all the data recorded in the tables have to be faithfully displayed on the graph.
- ❖ All presentations of data, tables and graphs calculations should be neatly and carefully done.
- ❖ Draw necessary graph for each of experiment. Learn to optimize on usage of graph papers.
- ❖ Graphs should be neatly drawn with pencil. Always label graphs and the axes and display units.
- ❖ If you finish early, spend the remaining time to complete the calculations and drawing graphs. Come equipped with calculator, scales, pencils etc.
- ❖ Do not fiddle idly with apparatus. Handle instruments with care. Report any breakage to the Instructor. Return all the equipment you have signed out for the purpose of your experiment.
- ❖ Don't make unauthorized modifications to the equipment. Don't use any kind of tape, markers, or ink on laboratory equipment.

Laboratory Planning

Subject: Engineering Physics (Subject Code: __________)

Academic Year: __________ (Semester: ___)

Month	Days	SCHEDULE		Remarks
		Laboratory orientation		
		Experiment – 1, 2		
		Experiment - 3		
		Experiment - 4	**Assignments**	
		Experiment – 5	**Assignments**	
		Experiment - 6	**Assignments**	
		Experiment - 7	**Assignments**	
		Experiment - 8	**Assignments**	
		Experiment - 9	**Assignments**	
		Experiment – 10	**Assignments**	
		Final submission & Revision of experiments		
		Final submission & Revision of experiments		
		Practical Examination		

Instructions:

- **100 % attendance is compulsory in labs**
- **Experiments should be performed as scheduled**
- **All have to perform the experiment individually**
- **Observation table need to be signed on the same day of performance of each experiment**
- **Calculations should show at the left page of the manual**
- **Submission of each experiment should be done on the consecutive labs on a regular basis**
- **One experiment can submit at a time**
- **Assignments /review questions should write at par with the lecture schedule and submit in the scheduled lab**

INDEX

EXPERIMENT 1

Error Analysis

Objectives

1. Combining and reporting uncertainties and error propagation in measurements using Vernier caliper and micrometer Screw gauge.
2. Estimation of the uncertainty in an averaged measurement

Introduction to Uncertainties and Error Propagation

It is impossible to do an experimental measurement with perfect accuracy. There is always an uncertainty associated with any measured quantity in an experiment even in the most carefully done experiment and despite using the most sophisticated instruments. This uncertainty in the measured value is known as the error in that particular measured quantity. There is no way by which one can measure a quantity with one hundred percent accuracy. In presenting experimental results it is very important to objectively estimate the error in the measured result. Such an exercise is very basic to experimental science. The importance of characterizing the accuracy and reliability of an experimental result is difficult to understate when we keep in mind that it is experimental evidence that validate scientific theories. Likewise, reliability and accuracy of measurements are also deeply relevant to Engineering.

When a measurement of a physical quantity is repeated, the results of the various measurements will, in general, spread over a range of values. This spread in the measured results is due to the errors in the experiment. Errors are generally classified into two types: systematic (or determinate) errors and random (or indeterminate) errors. A systematic error is an error, which is constant throughout a set of readings. Systematic errors lead to a clustering of the measured values around a value displaced from the "true" value of the quantity. Random errors on the other hand, can be either positive or negative and lead to a dispersion of the measurements around a mean value. For example, in a time period measurement, errors in starting and stopping the clock will lead to random errors, while a defect in the working of the clock will lead to systematic error.

Common sources of error in physics laboratory experiments:

Incomplete definition:
One reason that it is impossible to make exact measurements is that the measurement is not always clearly defined. For example, if two different people measure the length of the same rope, they would probably get different results because each person may stretch the rope with a different tension. The best way to minimize definition errors is to carefully consider and specify the conditions that could affect the measurement.

Failure to account for a factor:
The most challenging part of designing an experiment is trying to control or account for all possible factors except the one independent variable that is being analyzed. For instance, you may inadvertently ignore air resistance when measuring free-fall acceleration or you may fail to account for the effect of the Earth's magnetic field when measuring the field of a small

magnet. The best way to account for these sources of error is to brainstorm with your peers about all the factors that could possibly affect your result. This brainstorm should be done *before* beginning the experiment so that arrangements can be made to account for the confounding factors before taking data. Sometimes a *correction* can be applied to a result *after* taking data to account for an error that was not detected.

Environmental factors:
Be aware of errors introduced by your immediate working environment. You may need to take account for or protect your experiment from vibrations, drafts, changes in temperature, and electronic noise or other effects from nearby apparatus.

Instrument resolution:
All instruments have finite precision that limits the ability to resolve small measurement differences. For instance, a meter stick cannot distinguish distances to a precision much better than about half of its smallest scale division (0.5 mm in this case). One of the best ways to obtain more precise measurements is to use a *null difference* method instead of measuring a quantity directly. *Null* or *balance* methods involve using instrumentation to measure the difference between two similar quantities, one of which is known very accurately and is adjustable. The adjustable reference quantity is varied until the difference is reduced to zero. The two quantities are then balanced and the magnitude of the unknown quantity can be found by comparison with the reference sample. With this method, problems of source instability are eliminated, and the measuring instrument can be very sensitive and does not even need a scale.

Failure to calibrate or check zero of instrument:
The calibration of an instrument should be checked before taking data whenever possible. If a calibration standard is not available, the accuracy of the instrument should be checked by comparing with another instrument that is at least as precise, or by consulting the technical data provided by the manufacturer. When making a measurement with a micrometer, electronic balance, or an electrical meter, always check the zero reading first. Re-zero the instrument if possible, or measure the displacement of the zero reading from the true zero and correct any measurements accordingly. It is a good idea to check the zero reading throughout the experiment.

Physical variations:
It is always wise to obtain multiple measurements over the entire range being investigated. Doing so often reveals variations that might otherwise go undetected. These variations may call for closer examination, or they may be combined to find an average value.

Parallax:
This error can occur whenever there is some distance between the measuring scale and the indicator used to obtain a measurement. If the observer's eye is not squarely aligned with the pointer and scale, the reading may be too high or low (some analog meters have mirrors to help with this alignment).

Instrument drift:
Most electronic instruments have readings that drift over time. The amount of drift is generally not a concern, but occasionally this source of error can be significant and should be considered.

Lag time and **hysteresis**:
Some measuring devices require time to reach equilibrium, and taking a measurement before the instrument is stable will result in a measurement that is generally too low. The most common example is taking temperature readings with a thermometer that has not reached thermal equilibrium with its environment. A similar effect is *hysteresis* where the instrument readings lag behind and appear to have a "memory" effect, as data are taken sequentially

moving up or down through a range of values. Hysteresis is most commonly associated with materials that become magnetized when a changing magnetic field is applied.

Personal errors:

Come from carelessness, poor technique, or bias on the part of the experimenter.

The experimenter may measure incorrectly, or may use poor technique in taking a measurement, or may introduce a bias into measurements by expecting (and inadvertently forcing) the results to agree with the expected outcome.

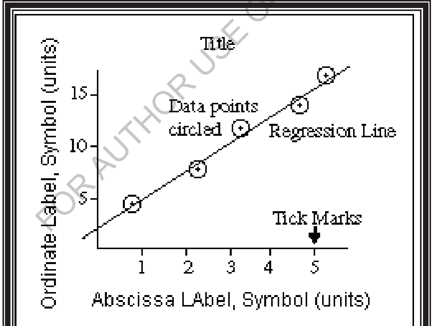
Uncertainties and graph

Graphs are a means of summarizing data so that the results may be easily understood. Working graphs are done on fine grid graph paper so that data may be easily read from the graph. New data may be extracted from the graph that would be hard to otherwise obtain.

Use of graphs in experimental physics

In practical physics, the graph of the experimental data is most important in improving the understanding of the experimental results. Moreover from the graphs one can calculate unknowns related to the experiments and one can compare the experimental data with the theoretical curve when they are presented on same graph. There are different types of graph papers available in market. So, one should choose the appropriate type of graph paper to present their experimental results in the best way depending upon the values of the experimental data and the theoretical expression of the functions. To understand all those some of the assignments are given below in addition to those we discussed before.

Basic layout of a graph



Some basic parts of a graph

(a) The horizontal axis is called the **abscissa** and the vertical axis is called the **ordinate**. You can use the terms horizontal and vertical just as well.
(b) The graph must have a **title** which clearly states the purpose of the graph. This should be located on a clear space near the top of the graph. The **title should uniquely identify the graph** --you should not have three graphs with the same title. You may wish to elaborate on the title with a brief caption. Do not just repeat the labels for the axes.
(c) The **scale** should be chosen so that it is **easy to read**, and so that it makes the **data occupy more than half of the paper**. Good choices of units to place next to major divisions on the paper are multiples of 1, 2, and 5. This makes reading subdivisions easy. **Avoid other numbers**, especially 3, 6, 7, 9, since you will likely make errors in plotting and in reading values from the graph. The **zero of a scale** does not need to appear on the graph.

(d) **Tick marks** should be made next to the lines for major divisions and subdivisions. Logarithmic scales are pre-printed with tick marks.
(e) **Axis label**. The **axes should be labelled with words and with units** clearly indicated. The words describe what is plotted, and perhaps its symbol. The units are generally in parentheses.
(f) Data should be plotted as precisely as possible, with a **sharp pencil and a small dot**. In order to see the dot after it has been plotted, put a **circle or box around the dot**. If you plot more than one set of data on the same axes use a circle for one, a box for the second, etc.,

Curve Fitting

We are free to make many plots from a given set of data. For instance if we have position (x) as a function of time (t) we can make plots of x versus t, x versus t^2, log(x) versus t, or any number of any choices. If possible, we **choose our plot so that it will produce a straight line**. A straight line is easy to draw, we can quickly determine slope and intercept of a straight line, and we can quickly detect deviations from the straight line.

If we have the guidance of a theory we can choose our plot variables accordingly. If we are using data for which we have no theory we can empirically try different plots until we arrive at a straight line. Some common functions are listed in Table 1 along with plots which yield straight lines.

Table 1. Different graphs for different functions.

This summarizes some of the most common mathematical relations and the graphing techniques needed to find slopes and intercepts.

Form	Plot (to yield a straight line)	Slope	Y-Intercept
$Y = a x + b$	y versus x on linear graph paper	a	B
$Y^2 = c x + d$	y^2 versus x on linear graph paper	c	d
$Y = a x^m$	log y versus log x on linear paper or y versus x on log-log paper	m *	log a a (at x = 1)
$X y = K$	y versus (1/x) on linear paper	K	0
$Y = a e^{bx}$	ln y versus x on linear paper or y (on log scale) versus x on semi-log paper	b*	ln a a

* Special techniques are needed when using logarithmic graph paper. These will be discussed in a later section.

Straight line graphs on linear graph paper

Suppose that we have plotted a graph with Y on the ordinate and X on the abscissa and the result is a straight line. We know that the general equation for a straight line is Y = M X + B where **M is the <u>slope</u>** and **B is the <u>intercept</u>** on the Y-axis (or **<u>Y-intercept</u>**).
The capital forms of Y and X are chosen to represent any arbitrary variables we choose to plot. For example we may choose to plot position, x, on the Y-axis versus mass, m, on the X-axis, so we need different symbols for our general case. Refer to Figure 4 to see what is being done.
We choose two points, (X_1, Y1) and (X_2, Y2), from the straight line that are **not data points** and that **lie near opposite ends of the line** so that a precise slope can be calculated. (Y_2-Y_1) is called the **<u>rise</u>** of the line, while (X_2-X_1) is the **<u>run</u>**. The slope is

$$Slope = M = \frac{Y_2 - Y_1}{X \;\; - X_1}$$

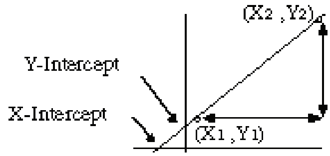


Fig. shows the intercepts and poits used to find the slope

The point where the line crosses the vertical axis is called the **intercept** (or the **Y-intercept**). The **intercept has the same units as the vertical axis**. The equation of the straight line with Y on the vertical axis and X on the horizontal axis is

$$Y = (Slope)X + (Intercept)$$

The line can be extended to cross the horizontal axis as well. The value of X where this happens is called the **X-intercept**, with the same **units as variable X**, and will be used only rarely.

If the line goes directly through the origin, with intercepts of zero, we say that **Y is directly proportional to X**. The word proportional implies that not only is there a linear (straight line) relation between Y and X, but also that the **intercept is zero**.

Error Bars

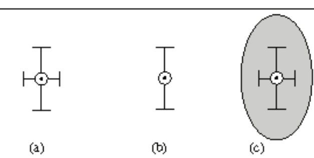
Data that you plot on a graph **will have experimental uncertainties**. These are shown on a graph with **error bars**, and used to find uncertainties in the slope and intercept. In this discussion we will describe simple means for finding uncertainties in slope and intercept; a full statistical discussion would begin with "Least Squares Fitting."

Consider a point with coordinates X ± ΔX and Y ± ΔY.

(a) Plot a point, circled, at the point (X, Y).

(b) Draw lines from the circle to X + ΔX, X - ΔX, Y + ΔY, and Y - ΔY and put bars on the lines, as shown in Figure 6(a). These are called **error bars**.

(c) The true value of the point is likely to lie somewhere in the oval whose dimension is two deviations, i.e. twice the size of the error bars.



Error bars for data points. (a) General case of error bars in horizontal and vertical (b) Error bars only in vertical (c) True value of data should lie in oval whose axes are twice the respective error bars, suggested here.

The oval shown in Figure shows the uncertainty region. It is not usually drawn on graphs. Often the error bars may be visible only for the ordinate (vertical), as Figure b.

Propagation of Errors

The following table summarizes the results for combining errors for some standard functions.

Sr. No	Function	Error in Δz
1.	z = x + y	$\Delta z = \lvert\Delta x\rvert + \lvert\Delta y\rvert$
2.	z = x – y	$\Delta z = \lvert\Delta x\rvert + \lvert\Delta y\rvert$
3.	z = x y	$\frac{\Delta z}{z} = \frac{\Delta x}{x} + \frac{\Delta y}{y}$
4.	z = x/y	$\frac{\Delta z}{z} = \frac{\Delta x}{x} + \frac{\Delta y}{y}$
5.	$z = x^m y^n$	$\frac{\Delta z}{z} = \lvert m\rvert \frac{\Delta x}{x} + \lvert n\rvert \frac{\Delta y}{y}$
6.	Arithmetic mean $\bar{x}$	$\left[\frac{1}{N}\sum_{i=1}^{N}(x_i)\right]$
7.	Relative error	$\frac{\Delta x_{mean}}{x_{mean}}$
8.	Percentage error	$\frac{\Delta x_{mean}}{x_{mean}} \times 100$
9.	Standard deviation, σ	$\sqrt{\left(\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2\right)}$
10.	Standard error	$\frac{\sigma}{\sqrt{N}}$

Principle of vernier calipers:

N divisions on the vernier scale are equal to (N-1) divisions on the main scale.

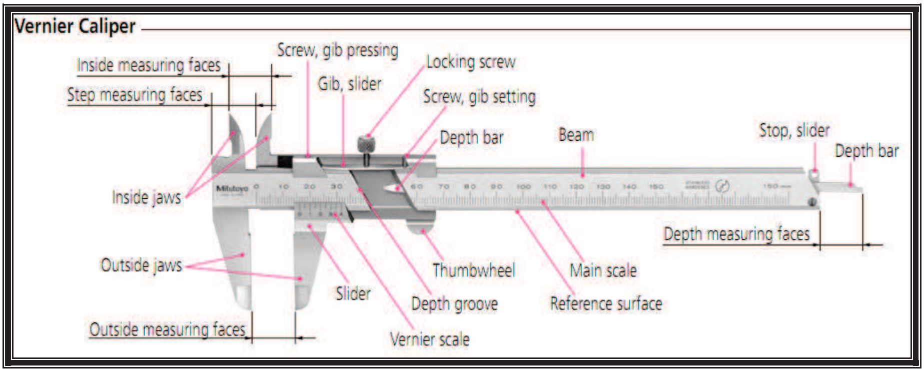


Figure: Vernier Callipers

$$\text{N V.S.D} = (\text{N}-1)\ \text{M.S.D} \quad \text{and} \quad 1\ \text{V.S.D} = \frac{(\text{N}-1)}{\text{N}}\ \text{M.S.D}$$

Least count (L.C) of vernier calipers:

Minimum length or thickness measurable with the vernier caliper is called its least count.

Least count (L.C) of vernier caliper $= 1\ \text{M.S.D} - 1\ \text{V.S.D}$

$$= 1\ \text{M.S.D} - \frac{(\text{N}-1)}{\text{N}}\ \text{M.S.D}$$

$$= 1\ \text{M.S.D}\left[1 - \frac{(\text{N}-1)}{\text{N}}\right]$$

$$= \frac{1\ \text{M.S.D}}{N} = \frac{S}{N}$$

Where S is the value of one Main scale division and N is the number of equal divisions on the vernier scale. **The total reading = M.S.D + (V.S.D x L.C)**.

Principle of micrometer screw gauge:

Micrometer screw works on the principle of screw and nut. When a screw is turned through a nut through one revolution, it advances by one pitch distance i.e. one revolution of the screw corresponds to linear movement of a distance equal to pitch of the thread.

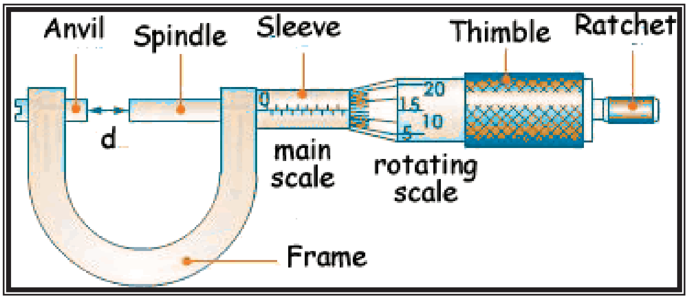
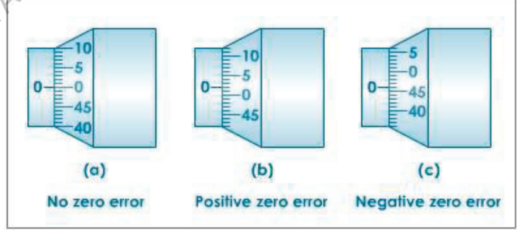


Figure: Micrometer Screw Gauge

Pitch: Perpendicular distance between two consecutive threads of the screw gauge (linear scale) or spherometer is called PITCH. Pitch of the screw is the distance moved by the spindle per revolution. Hence in this case, for one revolution of the screw the spindle moves forward or backward 0.5 mm.

The hollow cylinder leads to a ratchet which is meant for fine adjustment.

Least count (L.C) of micrometer screw gauge:
Least count is the minimum distance which can be measured accurately by the instrument.
The least count of a micrometer screw is the pitch of the screw divided by the number of divisions on the circular scale.
Least count (L.C) of micrometer screw=



$$\frac{\text{Pitch of spindle screw}}{\text{No. of divisions on the Thimble}} = \frac{0.5}{50} = 0.01\ mm$$

Zero Error: It is a defect in a measuring device (Vernier Callipers & Screw Gauge).When jaws of a Vernier Callipers or Screw Gauge are closed, zero of main scale must coincide with the zero of Vernier scale or circular scale in case of screw gauge.

If they do not coincide then it is said that a zero error is present in the instrument.

Types of Zero Error:
Zero error may be positive or negative.

A positive zero error in the instrument shows a larger measurement than the actual measurement.
In order to get exact measurement, positive zero error is subtracted from the total reading.

A negative zero error in the instrument shows a smaller measurement than the actual measurement
In order to get exact measurement, negative zero error is added to the total reading.

Procedure

1. Clean the workpiece and instruments.
2. Check the Vernier caliper for errors like play in the jaw, zero error if any.
3. If any error is present, correct it.
4. Calculate the least count of the instrument.
5. Hold the workpiece in the measuring jaws.
6. Note down the readings of main scale and Vernier scale/micro meter screw.
7. Complete the observation table.
8. All the calculations are required to be done in accordance with error analysis.

Precautions

1. Make sure that the Vernier calipers /micrometer screw guage is rest free smooth with all the division markings observable.
2. Ensure that the zero error is worked out properly before actual measurement.
3. The object must be held tightly between the jaws.
4. All measurements must be done without parallax error.
5. Do not apply undue pressure.

Observations

To measure the inner volume of a given cylindrical body using Verniar calipers

Sr. No.	Inner diameter (D) *cm*	Absolute error in the measurement of diameter $\Delta D = \lvert D_{mean} - D \rvert$ *cm*	Length of the cylinder (L) *cm*	Absolute error in the measurement of length $\Delta L = \lvert L_{mean} - L \rvert$ *cm*	Inner volume ($V = \pi r^2 L$) cm^3	Absolute error in the measurement of inner volume $\Delta V = \lvert V_{mean} - V \rvert$ cm^3
1.						
2.						
3.						
4.						
5.						
	D_{mean} = …...cm	ΔD_{mean} = ………cm	L_{mean} = ...cm	ΔL_{mean} = …………cm	V_{mean} = …...cm^3	ΔV_{mean} = …………cm^3
	$D_{mean} \pm \Delta D_{mean}$ = …………cm		Lmean ± ΔLmean = ……..…cm		Vmean ± ΔVmean = ……...cm^3	

Note: All the calculation are required to be done in accordance with error analysis

Conclusions

Relative error in the measurement of volume = …………….

Percentage error in the measurement of volume =…………..…

Standard deviation, σ =……………. cm^3

Standard error = …………….. cm^3

Observations

To measure the diameter of a given sample using micrometer screw gauge.

Sr. No.	**diameter (D)** ***cm***	**Absolute error in the measurement of diameter** $\Delta D = \lvert D_{mean} - D \rvert$ ***cm***	**Volume V =(4/3)πr³** ***cm³***	**Absolute error in the measurement of inner volume** $\Delta V = \lvert V_{mean} - V \rvert$ ***cm³***
1.				
2.				
3.				
4.				
5.				
	D_{mean} = …...cm	ΔD_{mean} = ………cm	V_{mean} = …...cm^3	ΔV_{mean} = …………cm^3
	$D_{mean} \pm \Delta D_{mean}$ = …………cm		Vmean ± ΔVmean = ……....cm^3	

Note: All the calculation are required to be done in accordance with error analysis

Conclusions

Relative error in the measurement of volume = …………….

Percentage error in the measurement of volume = …………..…

Standard deviation, σ =……………. cm^3

Standard error = …………….. cm^3

Calculation:

Sign of the faculty: Date:

Review questions

1. What is the general classification of errors? Give an example of each. How are they taken care of?
2. Consider an experiment to measure the gravitational acceleration 'g' by measuring the time period of a simple pendulum. What are the possible sources of systematic error in this experiment?
3. A small marble stone rests on top of a horizontal table. The radius (r) of the marble is measured using a micrometer screw gauge (with vernier least count 0.01 mm) to be 3.40 ± 0.05 mm. The height of the table is found using an ordinary meter scale to be 80 ±1 cm. What is the total height from the floor to the centre of the steel ball (include the error)?
4. Why should we care about errors?
5. The initial and final temperatures of a water bath are $(18 \pm 0.5)^0 C$ and $(40 \pm 0.3)^0 C$. What is the rise in temperature of the bath?
6. Write down the significant figures for the following. (i) 52038N, (ii) 0.023540, (iii) 35007.0 and (iv) 34.0180
7. (i) In successive measurements for the period of oscillation of a simple pendulum, the readings turn out to be 2.63 s, 2.56 s, 2.42 s, 2.71s and 2.80 s. Calculate the absolute error, relative error and percentage error.
   (ii) The Power P = VI, where V = (600 ± 0.5) V and I = (80 ± 0.2) A. Find the percentage error in P.
8. The force acting on an object of mass "m" travelling at velocity "v" in a circle of radius "r" is given by $F = {mv^2}/{r}$. The measurements are recorded as m = (3.5 ± 0.1) kg, v = (20 ± 1) m/s and r = (12.5 ± 0.5) m. Find the maximum possible (i) fractional error and (ii) percentage error in the measurement of force.
9. Calculate the following by taking significant figures in consideration.
   i) $4.9 \times 10^5 - 2.5 \times 10^4$ ii) $4.0 \times 10^{-4} - 2.5 \times 10^{-6}$
   iii) 316.7 + 10.04 iv) $9.5 \times 10^{-6} + 3.0 \times 10^{-8}$
10. In a projectile motion experiment suppose you have the following series of measurements of the distance x travelled by the projectile: 30.3 cm, 32.5 cm, 29.7 cm, 28.4 cm, 31.3 cm, 27.8 cm, 33.1 cm, 32.5 cm, 30.8 and 31.5 cm. Calculate the standard deviation and standard error in the measurement of length.
11. Calculate z and □z for each of the following cases.

(i) z = (x - 2.5 y + w) for x = (9.72 ± 0.12) m, y = (4.4 ± 0.2) m, w = (15.63 ± 0.16) m.

(ii) z = (w x/y) for w = (14.42 ± 0.03) m/s^2, x = (3.61 ± 0.18) m, y = (650 ± 20) m/s.

(iii) z = x^3 for x = (4.55 ± 0.15) m.

(iv) z = v (xy + w) with v = (0.664 ± 0.004) m, x = (3.42 ± 0.06) m, y = (6.00 ± 0.12) m, w = (13.13 ± 0.08) m^2.

12. Round of the following numbers as indicated. (i) 25.653 to 3 digit, (ii) 483.250 to 4 digit, (iii) 40.8995 to 1 digit and (iv) 3.435 to 2 digit
13. Experimental data (in arbitrary units) of some experiment is given below:

X	39	45	36	47	48	56	68	67	72	82
Y	47	56	48	55	69	85	97	107	106	123

a) Assuming 10% of error in Y values, plot the data on preferred graph paper showing the errors in terms of error bars.
b) Calculate the slope and intercept of the best fit graph.

14. Expression of some function is given by, $Y=a\ X^{b}$, where 'a', 'b' are unknown. Use the following experimental data to find out the constants by plotting an appropriate graph of X vs. Y.

X	253	275	357	419	541	663	785	907	1029	1151	1273	1395
Y	1265	1375	1785	2095	2705	3315	3925	4535	5145	5755	6365	6975

15. You are given a ruler, vernier caliper and a micrometer screw gauge to measure the diameter of a coin. Which of the three instruments given, do you think to make the most precise measurement? Why?
16. The mean diameter of a thin brass rod is to be measured by vernier callipers. Why is a set of 100 measurements of the diameter expected to yield a more reliable estimate than a set of 5 measurements only?
17. What are the criteria for selection of measuring instrument for a particular measurement?
18. How the zero error in the measuring instrument is removed or adjusted?
19. Measure the length of the workpiece with a scale in meter. Calculate the error in your measurement. Comment on the result.

EXPERIMENT 2

Multimeter measurements on dc resistive circuits

Objective

Measurement of resistance using the multimeters provided in the lab.

Apparatus

Resistors, wires with banana terminals, digital multimeter (DMM), *etc.*

Theory

Multimeter (Avometer)

An ammeter is a measuring instrument used to measure the electric current in a circuit. Electric currents are measured in amperes (A), hence the name. Smaller values of current can be measured using a milliameter or a microammeter known as a volt/ohm meter or VOM, is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as the ability to measure voltage, current and resistance. There are two categories of multimeters, analog multimeters and digital multimeters (often abbreviated DMM or DVOM.).

Procedure

Resistance Measurements

1. Turn the meter ON and Turn the rotary switch on the multi-meter towards Ω for Resistance Measurement. Insert two wires in the jacks labeled **VΩ** and **COM**. The multimeter can now be used to measure the resistance of a component connected between these two wires. Initially the meter reads OL MΩ because the resistance of an open circuit is infinity.
2. Measure the resistance of each of the five resistors and enter in the *Measured Value* column of the Data Sheet.
3. Determine the tolerance of each resistor as described on each component by the color of its band. A gold band represents 5%, a silver band represents 10%, and no band represents 20% tolerance. Enter in the *Tolerance* column of the Data Sheet.
4. Calculate the %Error for each resistor using the following formula: %Error = ((Nominal – Measured) / Nominal) x 100% Enter in the *%Error* column of the Data Sheet.

Continuity Testing

It's essential that circuits are continuous or complete, thereby allowing current to flow. Switches, fuses, conductors, and wire connectors demand good continuity. While good fuses and closed switches have good continuity, blown fuses and open switches have no continuity.

The continuity test on a DMM is simple. Set the dial to the continuity function (resistance mode). Plug in your lead. After ensuring that the power is off, make contact with the component under test using the leads. When the probes are not touching, the display shows "1". When you touch the tips together, the display changes to a three digit mode. It also emits a beep. The DMM will beep if there is good continuity, or a good path that allows current to flow. If there is no continuity, the DMM won't beep. Display shows "OL" which stands for Open Loop.

Observations

Resistance Measurements

Sr. No.	Color code	Tolerance (%)	Resistance R (Ω)	Measured Resistance R' (Ω)	Percentage Error (%)
1					
2					
3					
4					
5					

Precautions

1. Never connect an ammeter directly across a power supply as it will cause a short circuit and be damaged.
2. The ammeter must always be placed in series with the resistor and never parallel.
3. You can only test continuity when the device you're testing is not powered. Continuity works by poking a little voltage into the circuit and seeing how much current flows, it's perfectly safe for your device but if its powered there is already voltage in the circuit, and you will get incorrect readings.
4. **Switch off the multimeter** as soon as the completion of the experiment.

Conclusion:

Conclusions

1. A multimeter is acquainted for its testing of voltage, current and resistance.
2. Acquired proficiency in creating electrical circuits using resistors, wires, and power supplies.

Sign of the faculty: Date:

Review questions

1. What is the difference between resistor and resistance?
2. Suppose a piece of wire is connected to a battery. If the wire is heated, its resistivity increases. How would this increase in resistivity effect the following quantities: the resistance of the wire, the voltage drop across the wire, and the current passing through the wire?
3. Is Ohm's law universally applicable for all conducting elements? If not, give examples of elements which do not obey Ohm's law.
4. What is the physical significance of equation $\mathbf{E} = \rho\, \mathbf{j}$ leads to another statement of *Ohm's* law?
5. Why electrical conductivity of copper decreases with increase in temperature, whereas that of NaCl increases?
6. What is the effect of temperature on electrical resistivity of metals?
7. Tungsten rod and an aluminium rod have the same length and resistance.
   a. What is the ratio of the cross sectional area of the tungsten rod to the aluminium rod?
   b. What is the ratio of the diameter of the tungsten rod to the aluminium rod?
8. Given two lengths of metal wire, which one will have the least electrical resistance: one that is short, or one that is long? Assume all other factors are equal (same metal type, same wire diameter, etc.).
9. A three band resistor with all bands coloured red, except the tolerance band which is gold, has a resistance of _______ohms.
10. A conductor with a cross-sectional area of 2 mm^2 has a ________________ resistance than a conductor with a cross-sectional area of 4 mm^2.

EXPERIMENT 3

Diode characteristics

Objectives

1. Investigation of the I-V curve for given diode.
2. Study the characteristics of zener diode.

Apparatus

Theory

The semiconductor diode is formed simply by combining two main materials, n- type and p-type. There exist many electrons in n- type material whereas p- type material has many holes. When these two materials are combined, electrons of ntype material that are close to the junction fill the holes of p-type material that are also close to the junction as shown in Fig. 1.1(a). Consequently, the region of ntype material close to the junction is turned into positive ions and the region of p- type material close to the junction is turned into negative ions as shown in Fig. 1.1(b).

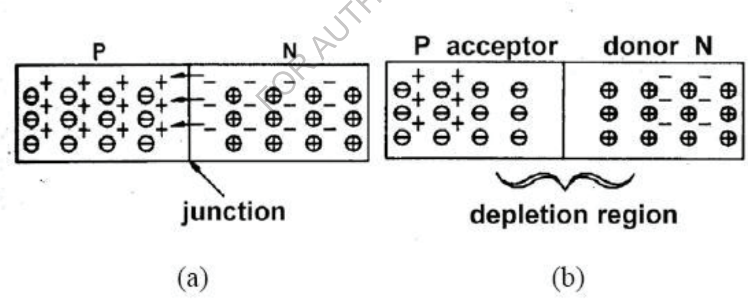


Fig. 1.1

Thus in the region close to the junction, the carriers (electrons & holes) are depleted, hereas only positive and negative ions can exist. This region is referred to as "**Depletion Region**".
The force that prohibits the electrons and holes from passing the junction due to the effect of ions in the depletion region is referred to as "**barrier voltage**". The typical barrier voltage in the p-n junction of germanium (Ge) is around 0.2 ~ 0.3 V, whereas it is around 0.6 V for silicon (Si).

Forward Bias:
As shown in **Fig. 1.2**, if the positive and negative terminals of the power supply are respectively connected to **p** and **n**, this connection is called "**forward bias**".

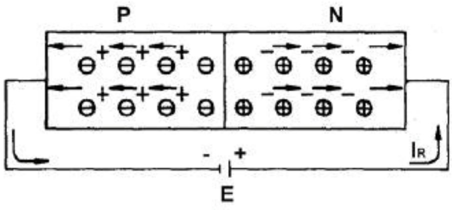


Fig 1.3

While the reverse bias is applied to the p-n junction, there shall be no reverse current in the ideal case. However, due to the effect of temperature, thermal energy will generate minority electron - hole pairs in the semiconductor. When the reverse bias is applied, the minority electrons in the **p**-type semiconductor can just cross the **p-n** junction to combine with the holes in the **n** terminal since the minority carriers exist in the semiconductor.When the reverse bias is applied to the p-n junction in practical operation, a very low current will exist. This current is referred to as "**leakage current**" or "**reverse saturation current**" denoted to be **IR** or **IS**.

IR is independent of the value of reverse bias, but is in relation to temperature. Regardless of germanium or silicon, the **IR** is doubled for every 100C of temperature rise. Under same temperature, **IR** of silicon diode is only 1 % ~ 0.1 % of that of germanium diodes. While **IR** of germanium diode is 1~2 _A, the diode applied with reverse bias is deem to be open – circuit at room temperature (250C).

Breakdown:

While the reverse bias is applied to the ideal **p-n** diode, **IR** is very low. However, if the applied revere bias is too high (higher than rated value), the minoritycarriers will acquire enough energy to impact and disintegrate the covalent bonds to generate signifivant amount of electron - hole pairs. These newly generated electrons and holes will acquire energy from higher reverse bias to disintegrate other covalent bonds. The movement of free electrons will be accelerated and the reverse current will thus be signifacantly increased. This phenomenon is referred to as "**breakdown**".

When the breakdown is found in the diode due to the increased reverse bias, the diode will burn down if the current is not limited. The maximum reverse voltage applied to the diode before its breakdown is called **"peak reverse voltage (PRV)"** or **"peak inverse voltage (PIV)".**

Assembly and symbol of a diode:

After combination of **n** and **p** type materials, the diode is completed by adding two lead wires to the terminals, then sealing the body with ceramics or glass (iron housing is supplemented for high-power diodes to facilitate heat dissipation). The internal structure of the diode is shown in **Fig 1.4 (a)**, its symbol in **Fig 1.4 (b)** and perspective view is shown in **Fig 1.4 (c).**

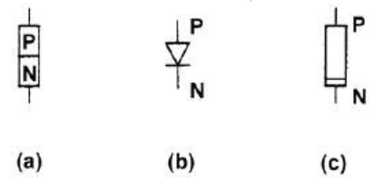


Fig 1.4

Characteristic Curve (V-I Curve) of Diode:

The forward characteristic curve is shown in first quadrant of **Fig. 1.5 (c).**

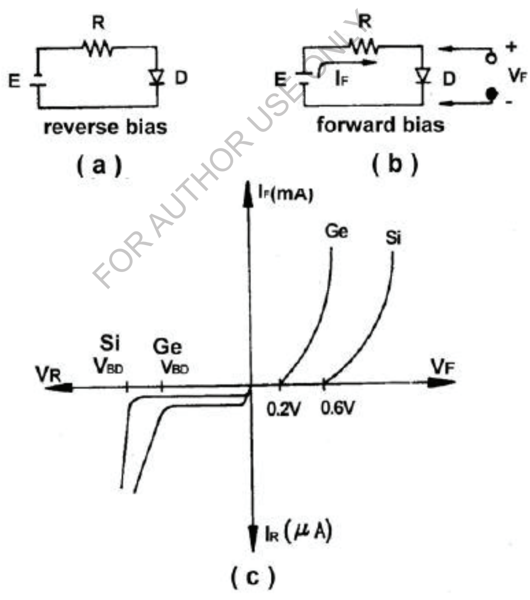


Fig. 1.5

From the characteristic curve we can see that the current is very low if the forward bias applied to the diode is lower than the cutin voltage (**Vr**). Once the forward biases exceed the cutin voltage (0.2 V for germanium diode, 0.6 V for silicon diode), the current (**IF**) will be dramatically increased, in the manner that the diode will function as short-circuit (with **VF** being around 0.7 V). The equivalent circuit is shown **in Fig 1.6.**

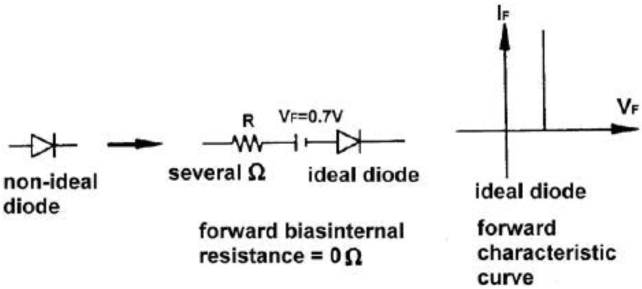


Fig. 1.6

Turning now to **Fig. 1.5**,the reverse characteristic curve of diode is shown in the fourth quadrant of **Fig 1.5 (c).** The reverse current before breakdown is very low, which can be treated as an open-circuit. When the reverse bias has reached the breakdown voltage, **IR** will be dramatically increased. As **Fig 1.5 (c)** reveals, silicon and germanium type diodes have different parameters, which are compared in the following table.

Items / Type	PIV	Temperature Range	Cutin Voltage (Vr)	Leakage Current (Ir)
Silicon	High	200^0C	0.7 V (0.6)	1/100~1/1000 of germanium
Germanium	Low	100^0C	0.3 V (0.2)	Several A

Table 1.1

1.3 **Other Two-terminal Devices with p-n Junction**

1.3.a **Zener Diode (ZD)**

Zener diode (also referred as regulated diode) is a two terminal device that is widely used in voltage regulators. As shown in the characteristic curve of diode (**Fig 1.5 (b)**), when the reverse bias, applied to the semiconductor, has reached to Vz , the current will be dramatically increased while the voltage keeps constant. The value of Vz can be controlled by changing the doping concentration. If the doping concentration is increased, the increased amount of impurity will decrease the value of Vz. The regulated values of the zener diode are thus distributed in the range from 3V to several hundreds of volts, whereas the power range is distributed from 200mW to 100W.

While applied reverse current Iz is lower than a specific Izmin , the zener diode can not be used for regulating voltage. Moreover, as ZD will burn down if **Iz** is , this time, higher than a specific **Izmax** , an adequate resistance should be connected to ZD in series. Typical regulating circuit is shown in **Fig 1.7.**

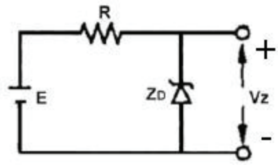


Fig. 1.7

The voltage that a ZD can regulate is called the zener voltage (Vz). The product of Vz and Izmax gives the maximum consuming power of each zener. That is;

$$PZ_{max} = V_Z \cdot I_{Zmax}$$

By these judgements, operating current range must be kept below **Izmax** and above **Izmin** . These boundaries are specific for each type of zener diode and are given in specification sheets of corresponding manufacturers. Symbol and appearance of Zener diode is given below.

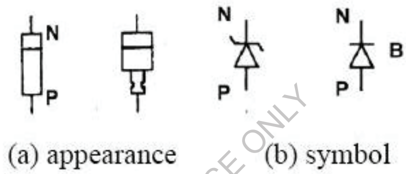


Fig. 1.8

Procedure

Forward Biased Condition:

1. Connect the PN Junction diode in forward bias i.eAnode is connected to positive of the power supply and cathode is connected to negative of the power supply .

2. Use a Regulated power supply of range (0-30)V and a series resistance of 1kΏ.

3. For various values of forward voltage (Vf) note down the corresponding values of forward current (I_f).

Reverse biased condition:

1. Connect the PN Junction diode in Reverse bias i.e; anode is connected to negative of the power supply and cathode is connected to positive of the power supply.

2. For various values of reverse voltage (Vr) note down the corresponding values of reverse current (Ir).

For Zener diode

Forward Biased Condition:

1. Connect the Zener diode in forward bias i.e; anode is connected to positive of the power supply and cathode is connected to negative of the power supply as in circuit

2. Use a Regulated power supply of range (0-30) V and a series resistance of 1kΏ.

3. For various values of forward voltage (Vf) note down the corresponding values of forward current (If).

Reverse biased condition:

1. Connect the Zener diode in Reverse bias i.e; anode is connected to negative of the power supply and cathode is connected to positive of the power supply as in circuit.

2. For various values of reverse voltage (Vr) note down the corresponding values of reverse current (Ir)

Observations:

Forward Bias (Diode):

S. No	Vf (volts)	If (mA)

Reverse Bias (Diode):

S. No	Vf (volts)	If (mA)

Forward Bias (Zener Diode):

S. No	Vf (volts)	If (mA)

Reverse Bias (Zener Diode):

S. No	Vf (volts)	If (mA)

Calculation:

Conclusions

PN Junction Diode:

Zener Diode:

Sign of the faculty: Date:

Review questions

1. Can we use Zener diode for rectification purpose?
2. What happens when the Zener diodes are connected in series?
3. What type of biasing must be used when a Zener diode is used as a regulator?
4. Current in a 1W – 10V Zener diode must be limited to a maximum of what value?
5. How will you differentiate the diodes whether it is Zener or avalanche when you are given two diodes of rating 6.2 v and 24V?
6. When current through a Zener diode increases by a factor of 2, by what factor the voltage of Zener diode increases.
7. Comment on diode operation under zero biasing condition
8. How does PN-junction diode acts as a switch?
9. What is peak inverse voltage?
10. What is the need for connecting Resistance Rs in series with PN diode.
11. What are the applications of PN junction diode?

EXPERIMENT 4

Ultrasonic Interferometer

Objectives

3. Calculate the ultrasonic velocity of given liquid sample.
4. Calculate compressibility of the given sample.

Apparatus

Ultrasound interferometer set up, high frequency generator, Measuring cell, Shielded cable, etc.

Theory

An Ultrasonic Interferometer is a simple and direct device to determine the ultrasonic velocity in liquids with a high degree of accuracy. The principle used in the measurement of velocity (v) is based on the accurate determination of the wavelength (λ) in the medium. Ultrasonic waves of known frequency (f) are produced by a quartz crystal fixed at the bottom of the cell. These waves are reflected by a movable metallic plate kept parallel to the quartz crystal. If the separation between these two plates is exactly a whole multiple of the sound wavelength, standing waves are formed in the medium. This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz crystal and the anode current of the generator becomes a maximum. If the distance is now increased or decreased and the variation is exactly one half wavelength ($\lambda/2$) or multiple of it, anode current becomes maximum. From the knowledge of wavelength (λ), the velocity (v) can be obtained by the relation:

$$\text{Velocity} = \text{Wavelength} \times \text{Frequency}; \; v = \lambda \times f$$

Description of the interferometer

The Ultrasonic Interferometer consists of the following parts:

a) The High Frequency Generator: 2 MHz

b) The Measuring Cell

(i) The High Frequency Generator is designed to excite the quartz crystal fixed at the bottom of the measuring cell at its resonant frequency to generate ultrasonic waves in the experimental liquid filled in the "Measuring Cell ". A micrometer to observe the changes in current and two controls for the purpose of sensitivity regulation and initial adjustment of the micrometer is provided on the panel of the High Frequency Generator.

(ii) The Measuring Cell is specially designed double walled cell for maintaining the temperature of the liquid constant during the experiment. A fine micrometer screw has been provided at the top, which can lower or raise the reflector plate in the liquid in the liquid in the cell through a known distance. It has a quartz crystal fixed at its bottom.

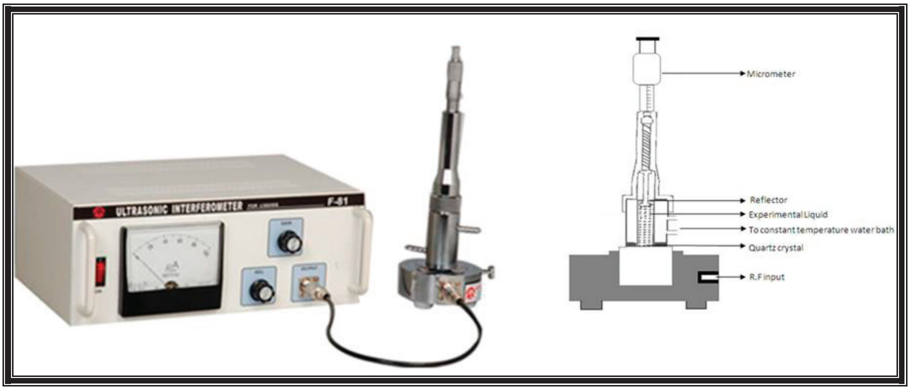


Fig. 1 Experimental Setup and Cross-Section of the Liquid Cell.

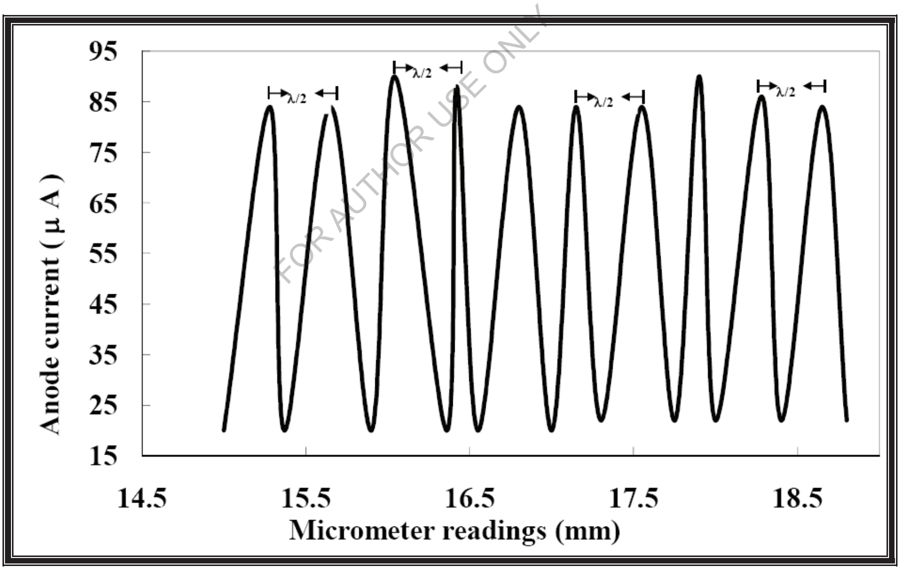


Fig. 2 Position of reflector vs crystal Current

Note: Extra peaks in between minima and maxima may occur due to a number of reasons, but they don't effect the value of $\lambda/2$.

Adjustments of ultrasonic interferometer

For initial adjustment two knobs are provided on high frequency generator, one is marked with "ADJ" to adjust the position of the needle on the Ammeter and the knob marked "GAIN" is used to increase or decrease deflection, if desired.

The ammeter is used to notice the number of maximas while micrometer is moved up and down in liquid.

Least count of micrometer screw gauge:

A screw's pitch is the distance it moves forward or backward axially with one complete turn.

The screw has a known pitch such as **0.5 *mm***. Hence in this case, for one revolution of the screw the spindle moves axially by **0.5 *mm.***

Least count = pitch /Number of div.on the circular scle = 0.5mm/50 = 0.01mm

Procedure

1. Insert the quartz crystal in the socket at the base and clamp it tightly with the help of a screw provided on one side of the instrument.

2. Unscrew the knurled cap of the cell and lift it away. Fill the middle portion with the experimental liquid and screw the knurled cap tightly.

3. Connect high frequency generator with the cell.

4. There are two knobs on the instrument- “Adj” and “Gain”. With “Adj”, position of the needle on the ammeter is adjusted. The knob “Gain” is used to increase the sensitivity of the instrument.

5. Move the micrometer till the anode current in the ammeter show a maximum and minimum.

6. Take order of deflection in the micrometer say n = 5 by observing the number of maxima readings of anode current are passed.

7. Note down the micrometer reading (d) corresponding to n maximum deflections.

8. Calculate the distance between successive maxima which is equal to $\lambda/2$ by d/n.

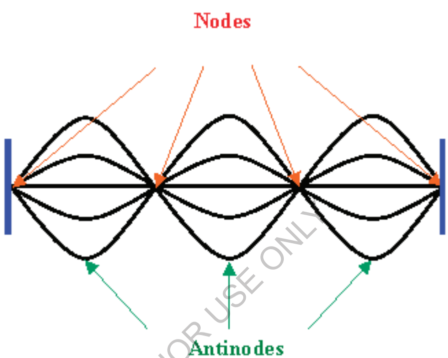
9. Calculate the wavelength by $\lambda = 2\,d/n$

10. Calculate the velocity of ultrasound through the medium as, $v = \lambda f$

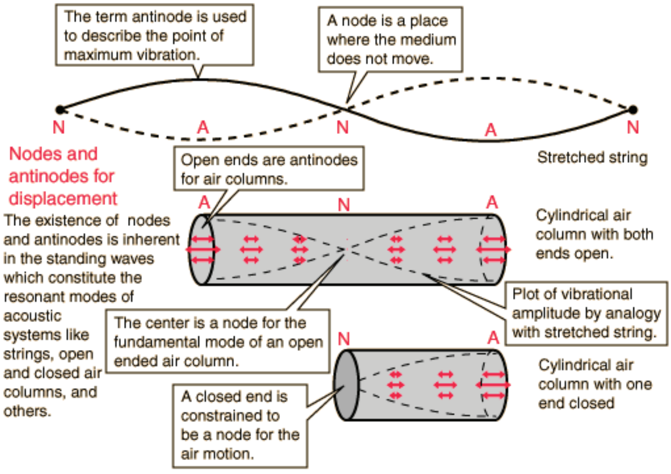
11. Knowing the density of the medium, the adiabatic compressibility can be calculated using the equation, $\beta = 1/\rho v^2$

Standing Wave

A standing wave is a pattern which results from the interference of two or more waves traveling in the same medium. All standing waves are characterized by positions along the medium which are standing still. Such positions are referred to as **nodes**. Standing waves are also characterized by **antinodes**. These are positions along the medium where the particles oscillate about their equilibrium position with maximum amplitude. Standing wave patterns are always characterized by an alternating pattern of nodes and antinodes.



The antinodes are separated by $\lambda/2$ and are located half way between pairs of nodes (distance between consecutive nodes is also half a wavelength).



Precautions

1. Do not switch on the generator without filling the experimental liquid in the cell.
2. Remove experimental liquid out of cell after use and keep it clean and dry.
3. Keep micrometer open at 25 mm after use.
4. While cleaning the cell, care should be taken not to spoil or scratch the gold plating on the quartz crystal.

Give your generator 15 seconds warming up time before observation.

Calculation:

Observations

FOR SAMPLE I				
Order of deflection in micrometer	**Micrometer Reading corresponding to n maximum deflections, d** (*mm*)	**Distance between successive maxima d/n** (*mm*)	**Wavelength $\lambda = 2\ d/n$** (*mm*)	**Ultrasound velocity $v = f\ \lambda$** (*m/s*)
n = 5				
n = 10				
n = 15				
n = 20				
n = 25				
n = 30				
n = 35				
n = 40				
n = 45				
n = 50				

Frequency f = **2 MHz**

Density = ____________ *kg/m*^{3}

Average Velocity = _____________*m/s*

Compressibility = _____________ *m*^{2}*/N*

Conclusions

1. Velocity of ultrasound of given sample ______________ m/s.
2. Compressibility of the given sample____________m^2/N.

Sign of the faculty: Date:

Review questions

1. How can one classify the sound on the basis of frequency? Explain each type with detail.
2. Why musical sound is so pleasant? What are the characteristics of a musical sound?
3. What is ultrasonic sound? How this kind of sounds are created?
4. What is the unit of sound? Explain difference between bel and decibel?
5. What is the full form of SONAR? Mention its application.
6. When sound travels through air, the air particles vibrate __________the direction of wave propagation. State the reason of it.
7. Bats detect the obstacles in their path by receiving the reflected __________. List the examples living species which undergo same process.
8. Which physical quantity is transferred during wave propagation? Why?
9. Sound travels fastest through: air / iron / water? Why?
10. List the methods used for ultrasonic sound detection. Explain one of them.
11. Describe any device where you think ultrasonic waves are used? Explain mechanism of that device.
12. Write types of waves. Show it using diagrams.

EXPERIMENT 5

Young's Modulus

Objectives

1. Calculate and compare the ultrasonic velocities in different solid samples.
2. Calculate Young's modulus of different solid samples.

Apparatus

Power supply 9 volts & R. F. meter (Resonant frequency meter) containing metal cabinet, Shielded cables, Crystal holder, Longitudinal crystal, Sample/Specimen, cementing glue *etc.*

Theory

Non-Destructive Testing of material is an important part of engineering education as it gives information without deformation in the shape and size of the material. One of the NDT techniques, Piezoelectric Technique is widely used for the measurement of composition dependent properties such as *ultrasonic velocity*, *compressibility*, *elastic constant*, *Young's modulus* and *Bulk modulus*. Its suitability for metals, plastics, polymers and crystals etc makes it versatile tool for *Engineering Physics, Material Science and Polymer Science*.
Ultrasonic velocity in solids is measured by Piezo-electric technique using this instrument and subsequently Young's Modulus is calculated. It is simple and elegant method and is used to evaluate the compressibility also. The electronic circuit is housed in a metal cabinet. Connections to the Crystal Holder and C.R.O. are made using cables.

Fig. 1 Experimental setup

Turn the potentiometer which provided with a calibrated dial to facilitate direct reading of the value of R*f*. The voltage across R*f* is fed back to the input of the amplifier. The system oscillates at the resonant frequency of the quartz when,

$$\frac{GR_f}{R_f + R_c} \geq 1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

where *Rc* is the resistance of the quartz at resonance. By varying *Rf*, the system can be made to oscillate. The oscillations are detected using Cathode Ray Oscilloscope and the frequency measured by digital frequency meter.

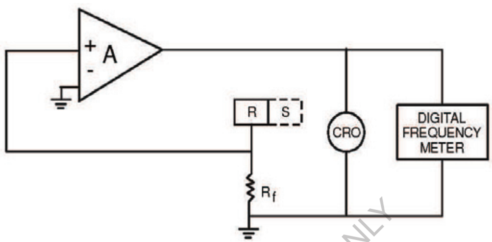


Figure 2

Figure 2 illustrates the principle of determining the resonant frequency. A is a specially designed amplifier having gain of 39 (G=38) in the frequency range of operation. The output of the amplifier is applied to the quartz rod in series with R*f*. The specimen in the form of rectangular rod for longitudinal oscillations is cemented to a quartz rod of identical cross-section and the resonant frequency (f_C) of the composite system is determined using the apparatus.

The resonant frequency of the quartz rod (f_q) is also determined. From the knowledge of f_q, f_C and masses of the quartz rod (m_q) and the specimen (m_S), the resonant frequency of the specimen f_S is evaluated using the relation

$$f_s = f_c + \frac{m_q}{m_s}\left(f_c - f_q\right) \qquad \ldots\ldots\ldots\ldots\ldots \qquad (2)$$

Using the value of f_S , the length of the specimen (L) and the density of the specimen, the longitudinal velocity of Ultrasonic waves in the specimen can be evaluated using relation:

$$v = 2 \cdot f_S \cdot L \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

Young's Modulus of specimen is calculated using relation

$$\gamma = 4.f_s^2 L^2 \rho \qquad \text{……..………… (4)}$$

From relation (3) and density of the specimen (ρ) the adiabatic compressibility can be calculated using relation

$$\beta_{ad} = \frac{1}{\rho v^2} \qquad \text{……………….. (5)}$$

Stress

Stress is defined as the force per unit area of a material. It also defined as the restoring force per unit area and strain is the unit deformation produced by the applied stress. In general there are three types of stresses (a) tensile stress (associated with stretching), (b) shearing stress, and (c) compressional or hydraulic stress.

i.e. Stress = force / cross sectional area: σ = F/A

where,
σ = stress,
F = force applied, and
A= cross sectional area of the object.
Units of s : Nm^{-2} or Pa.

Strain

Strain is defined as extension per unit length.

Strain = extension / original length; ε = e/l_0

where,
ε = strain,
lo = the original length
e = extension = (l-lo), and
l = stretched length
Strain has no units because it is a ratio of lengths.

For small deformations **stress** α **strain**. This is known as Hooke's law. The constant of proportionality is called a **modulus of elasticity**. Three elastic modulii are used to describe the elastic behaviour (deformation) of objects as they respond to deforming forces that act on them.

When an object is under tension or compression, the Hooke's law takes the form $F/A = Y\Delta L/L$ Where $\Delta L/L$ is the tensile or compressive strain of the object, *F* is the magnitude of the applied force causing the strain, *A* is the cross-sectional area over which *F* is applied (perpendicular to *A*) and *Y* is the Young's modulus for the object. The stress is F/*A*.

Specifying how stress and strain are to be measured, including directions, allows for many types of elastic moduli to be defined. The three primary ones are:

- *Young's modulus* (*E*) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of tensile stress to tensile strain. It is often referred to simply as the *elastic modulus*. Young's modulus is also called as the modulus for tensile or linear compressive stress. Dimensionally, the Young's modulus is a force per unit area and therefore has the unit N m^{-2} and is measured in pascals (Pa). Although the Young's modulus for an object may be almost the same for tension and linear compression, the object's ultimate strength may well be different for the two types of stress.

- The *shear modulus* or *modulus of rigidity* (*G*) describes an object's tendency to shear (the deformation of shape at constant volume) when acted upon by opposing forces; it is defined as shear stress over shear strain. The shear modulus is part of the derivation of viscosity.
- The *bulk modulus* (*K*) describes volumetric elasticity, or the tendency of an object to deform in all directions when uniformly loaded in all directions; it is defined as volumetric stress over volumetric strain, and is the inverse of compressibility. The bulk modulus is an extension of Young's modulus to three dimensions.

Procedure

1. Connect the longitudinal crystal holder with the main circuit using cords supplied with the instrument.
2. Connect with the main unit using co-axial supplied.
3. Insert the longitudinal quartz rod R in the crystal holder <u>such that the holder pins are approximately at the center of the plated electrode face of the crystal</u>.
4. Vary R_f (TTP) and observe the system oscillating (as indicated by the C.R.O. pattern) above a particular value of *Rf*. Measure resonant frequency of the quartz rod (f_q).

   <u>Note</u>*: Vary the TTP until you get the stabilized oscillations (or reading around 123 KHz -125 KHz).*
5. Cement the quartz rod to the specimen, in the form of rectangular rod of identical cross-section, using cementing glue provided.

   Now place the composite system in the crystal holder and by proper adjustment of Rf, measure the frequency of oscillations of composite system and minimum value of Rf that maintain oscillation as described above. In this case also <u>the holder pins are approximately at the center of the plated electrode face of the crystal</u>.
6. Using relations (2) and (3) calculate ultrasonic velocity in the sample and using relation (4) calculate compressibility.

Precautions

1. Quartz or the composite system oscillates only when it is mounted of its node (approximately near the centre of the crystal). Please fix the position by trial.
2. Use minimum amount of glue/cement. Excessive adhesive may damp the oscillations.
3. Be extremely careful while using the glue. It can adhere fast to the skin. If it drop on your finger, for example, gently massage it in pure acetone or Luke warm water to peel it off.

Calculation:

Observations

Sample: Aluminum specimen	Sample: Brass specimen
Mass of quartz rod, $m_q = 0.92\ gm$	Mass of quartz rod, $m_q = 0.92\ gm$
Mass of specimen, $m_s = 1.01 gm$	Mass of specimen, $m_q = 2.06\ gm$
Length of specimen, $L = 2.18\ cm$	Length of specimen, $L = 1.41\ cm$
Density, $\rho = 2700$ kg/m^3	Density, $\rho = 8400$ kg/m^3
Natural Frequency of quartz rod, $f_q = 123.893\ kHz$	Natural Frequency of quartz rod, $f_q = 123.893\ kHz$
Natural Frequency of composite system, $f_c =$ ________________ kHz	Natural Frequency of composite system, $f_c =$ ________________ kHz
Natural Frequency of specimen, $f_s = f_c + \frac{m_q}{m_s}\left(f_c - f_q\right) =$ ________ kHz	Natural Frequency of specimen, $f_s = f_c + \frac{m_q}{m_s}\left(f_c - f_q\right) =$ ________ kHz
Ultrasonic velocity in specimen, $v = 2 \cdot f_S \cdot L =$ ______________ m/s	Ultrasonic velocity in specimen, $v = 2 \cdot f_S \cdot L =$ ______________ m/s
Young's Modulus, $\gamma = 4.f_s^2 L^2 \rho =$ _________________ N/m^2	Young's Modulus, $\gamma = 4.f_s^2 L^2 \rho =$ _________________ N/m^2
Compressibility, $\beta = \frac{1}{\rho v^2} =$ ________________ m^2/N	Compressibility, $\beta = \frac{1}{\rho v^2} =$ ________________ m^2/N

Conclusions

1. Ultrasonic velocity in specimen aluminium = ________________ *m/s*
2. Ultrasonic velocity in specimen brass = ________________ *m/s*
3. Young's Modulus of specimen aluminium, γ = ________________ N/m^2
4. Young's Modulus of specimen brass, γ = ________________ N/m^2
5. Compressibility cf specimen aluminium, β = ________________ m^2/N
6. Compressibility cf specimen brass, β = ________________ m^2/N
7. Velocity of ultrasound in different solids are measured and compared.

Sign of the faculty: Date:

Review questions

1. What is Young's modulus, Bulk modulus and shear modulus?
2. Define Hook's law with example.
3. What is the different module of elasticity?
4. Define stress and strain.
5. Define pressure. What is its unit?
6. Define Magnetostriction and electrostriction. Explain any one of them.
7. Explain kund's tube method for detection of ultrasonic sound.
8. An ultrasonic source of 0.07 MHz sends down a pulse towards the seabeds which returns after 0.7 seconds. Assuming the velocity of sound in sea water as 1500 m/s, calculate the depth of sea and the wavelength of pulse.
9. Calculate the nature of frequency of ultrasonic wave using following data. (a) Thickness of quartz plate = 5.5×10^{-3} m. (b) Young's modules for quartz's = 8 × 1010 N/m^2. (c) Density of crystal = 2.65 × 103 kg/m^3.
10. List few applications of ultrasound.
11. Give types of noise which could affect good acoustics of auditorium.
12. What is reverberation, reverberation time and absorption coefficient?

EXPERIMENT 6

Wavelength of Laser

Objective

Determination of the wavelength of given Laser

Apparatus

Laser source, Optical bench, Transmission type grating (100 *lpmm*, 300 *lpmm*, 600 *lpmm*), Screen/ Graph paper, Scale.

Theory

The word "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers are finding ever-increasing military applications --principally for target acquisition, fire control, and training. These lasers are termed rangefinders, target designators, and direct-fire simulators. Lasers are also being used in communications, laser radars (LIDAR), landing systems, laser pointers, guidance systems, scanners, metal working, photography, holography, and medicine.

Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye. Diffraction Grating is optical device used to learn the different wavelengths or colors contained in a beam of light. The device usually consists of thousands of narrow, closely spaced parallel slits (or grooves). Because of interference the intensity of the light getting pass through the slits depends upon the direction of the light propagation. There are selected directions at which the light waves from the different slits interfere in phase and in these directions the maximums of the light intensity are observed. These selected directions depend upon wavelength, and so the light beams with different wavelength will propagate in different directions.

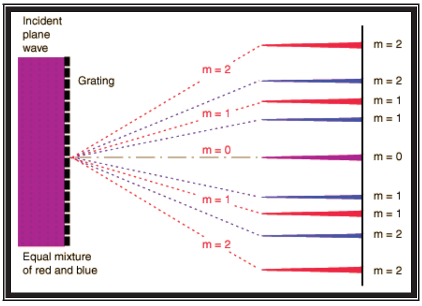


Fig. 1 Diffraction pattern

Procedure

(1) Level the optical bench.
(2) Place the LASER source on LASER holder and mount on the optical bench.
(3) Hold the transmission grating (100 lpmm) on the holder between LASER source and screen as shown in figure below.

(4) The LASER beam after passing through the grating will split into zero order, first order, and second order beam as shown in Fig.-1.

(5) Measure the distance between first order spot & zero[th] order spot & half of this distance

$$i.e.\ x_m = \left(\frac{x_{ml} + x_{mr}}{2}\right)$$

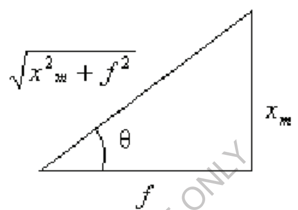


Fig. 2 – Third side of triangle

(6) From fig. 2, $\sin\theta_n = \dfrac{x_m}{\sqrt{x_m{}^2 + f^2}}$

(7) Put $\sin\theta_n$ as below,

$$n\lambda = d\sin\theta_n \qquad \text{-------- (a)}$$

$$\lambda = \frac{d \times x_m}{n\sqrt{x_m{}^2 + f^2}} \qquad \text{-------- (b)}$$

Where,

n = Order of spots (i.e. n = 1, 2, 3, 4, etc.)
λ = Wavelength of LASER beam.
d = Resolution of grating (=1/grating element, i.e. d = 1/ (100 or 300 or 600)).
x_m = Distance between zero order spot & first order spot (mm).
f = Distance between screen & grating element (mm).

(8) Write the observations in the observation table and repeat the experiment for the transmission gratings of 100 lpmm, 300 *lpmm* and 600 *lpmm*.

(9) Find the average wavelength of He-Ne laser.

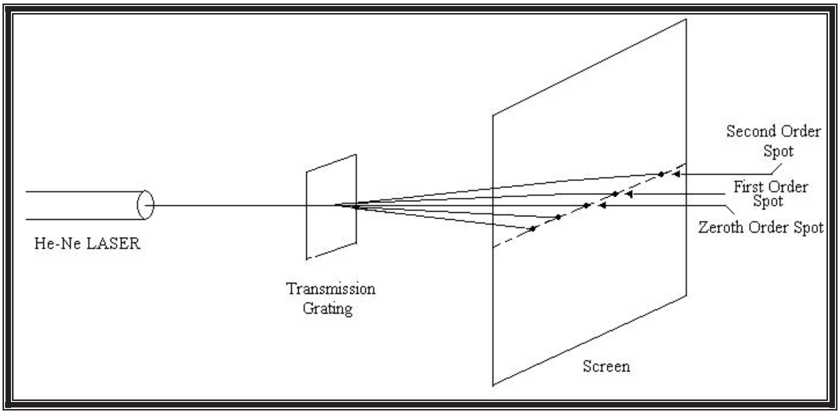


Fig. 3 Experimental setup

Precautions

(1) Do not see LASER directly, it can harm eyes. Beside this, reflected rays can also be harmful.

(2) Handle the apparatus carefully.

Calculation:

Observations:-

Grating element	Order of sport 'n'	Distance between screen & grating element (*mm*)	Distance between zeroth order spot & 1st, 2nd and 3rd order spot x_{ml} (*mm*)	x_{mr} (*mm*)	$x_m = \left(\frac{x_{ml}+x_{mr}}{2}\right)$ (*mm*)	Wavelength of He-Ne laser, λ (*nm*)	Average λ (*nm*)
100 lines/ mm	1						
	2						
	3						
300 lines/ mm	1						
	2						
	3						
600 lines/ mm	1						
	2						

Conclusion

The wavelength of He-Ne Laser = ____________________ *nm.*

Sign of the faculty: Date:

Review questions

1. What is laser? Write full form of laser.
2. Name the three processes that could occur when light interact with matter with diagrams.
3. List five applications of laser in detail.
4. Discuss, how laser differs from ordinary light?
5. What is population inversion? How to achieve population inversion?
6. What do you mean by pumping? Write different types of pumping.
7. What is a metastable state? Write importance of it in laser system.
8. Name few types of lasers and mention examples.
9. What is the difference between an active medium and active centre? Explain it with suitable example.
10. What is the ratio of population for energy levels corresponding to wavelength 1060 nm at 300K?
11. Frame the principle of laser in brief.
12. Draw schematic of laser.

EXPERIMENT 7

Planck's constant by LED

Objective

To estimate the Planck's constant based on the LED characteristics.

Apparatus

0-5V DC Power supply, Digital volt meter (DC), Digital microampere meter (DC), different colour LED'S (Red, Yellow, Blue, Green), Mains ON/OFF switch & Fuse.

Theory

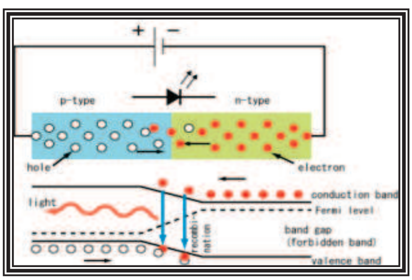
Max Planck first proposed the idea that light was emitted in discrete packets or quanta in order to avoid the infamous ultra-violet catastrophe. With one problem resolved other questions soon followed. Primarily, how big was a given packet. It was subsequently determined that the energy of given photon is given be the equation:

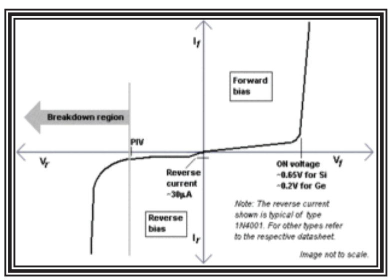
$$E = h\,v \qquad \text{….. (1)}$$

Where E is the energy of the photon, v is its frequency, and h is a constant.

• A light-emitting diode (LED) is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device. Like a normal diode, the LED consists of a chip of semiconducting material impregnated, or doped, with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side to the n-side, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon. The effect is a form of electroluminescence where incoherent light in a narrow-spectrum is emitted from the p-n junction

• The transport mechanism at the junction and the IV characteristic of an LED are shown below.





• An LED will begin to emit light when the on-voltage is exceeded. Typical on voltages are 2-3 Volt.
• The wavelength of the light emitted, and therefore its color, depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.
• LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever-shorter wavelengths, producing light in a variety of colors.
• LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate.
• The refractive index of most LED semiconductor materials is quite high, so in almost all cases the light from the LED is coupled into a much lower-index medium. The large index difference makes the reflection quite substantial (per the Fresnel coefficients). The produced light gets partially reflected back into the semiconductor, where it may be absorbed and turned into additional heat; this is usually one of the dominant causes of LED inefficiency. Often more than half of the emitted light is reflected back at the LED-package and package-air interfaces.
• The reflection is most commonly reduced by using a dome-shaped (half-sphere) package with the diode in the center so that the outgoing light rays strike the surface perpendicularly, at which angle the reflection is minimized. Substrates that are transparent to the emitted wavelength, and backed by a reflective layer, increase the LED efficiency. The refractive index of the package material should also match the index of the semiconductor, to minimize back-reflection. An anti-reflection coating may be added as well.

Methodology:

When P and N type semiconductors coupled together, it is called a P-N junction. In this system the bands don't always line up and there then exists a barrier potential. If a bias voltage is passed across the diode, which is equal or greater than the difference in the energy of the bands, i.e. the barrier potential, then the bands will 'line up' and a current will flow. When current flows, electrons flow from the conduction band of the N type conductor and are forced up into the conduction band of the P type. Since the p type conductor's valance band is lacking in electrons and we are overpopulating its conduction band with the bias voltage the electrons readily fall into the 'holes' in the valance band of the P type conductor. When they fall this energy is released in the form of a photon. The energy of this photon is equal to the band gap energy of the diode. It follows that if the linear portion of the voltage Vs. current graph is extrapolated back to the x-axis the intercept should be the point at which the voltage equals the barrier potential. The energy of the photons emitted should then be the same as the energy of given electron. The energy of electron is

$$E = e\,V \qquad \ldots\ldots (2)$$

Where $e = 1.6 \times 10^{-19}$ C (electron charge), V is the voltage which is equal to barrier potential. Then we compare equation (1) and (3), so we get h as

$$h\,\nu = eV \qquad \ldots\ldots. (3)$$

Here, v is the frequency of generated photon and we can also write in the form as

$$v = \frac{c}{\lambda} \quad \text{……. (4)}$$

Where c is the speed of light (c = 3 x 10^8 m/sec) and λ is the wavelength of respective photon.

The Eq. (3) becomes,

$$h = \frac{e\,V\,\lambda}{c} \quad \text{……. (5)}$$

This eq. cab be written as

$$V = \frac{h\,c}{e}\,\lambda^{-1} \quad \text{……. (6)}$$

PANEL DESCRIPTION:

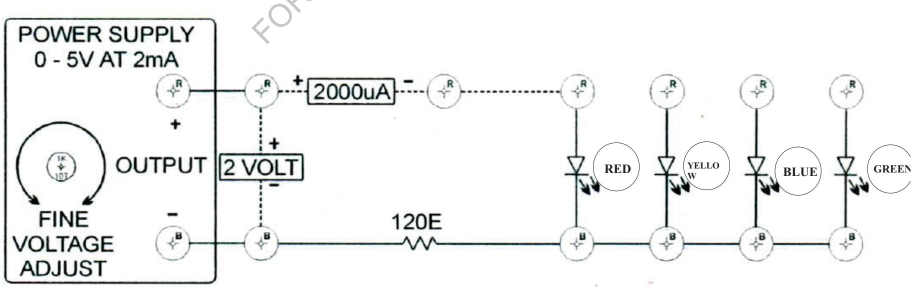
Front Panel Comprises of:

1. ONI OFF Switch SPOT & 100mA rating Fuse. at Left Bottom Corner.
2. Beside ONI OFF switch assembly variable D.C. power supply 0-5V at 20mA with 1K 10 turns potentiometer for fine voltage adjustment is provided.

3 Two digital panel meters D.C. voltmeter 0-20 volt & Ammeter 0-2000uA is provided on upper left & upper right corner.

4 Four LED's Red, Yellow, Blue & Green are provided.

CIRCUIT DIAGRAM:



PROCEDURE:

Connect the Planck's constant by LED kit to main power supply. The 5v DC voltage power supply is internally connected into circuit which is made by step down transformer and rectifier. For the voltage and current measurement, we connect the voltmeter and micro ampere meter from the above circuit. Take the different voltage and current measurement of given LED for V-I characteristic of LED. Take different LEDs and follow same procedure. Now plot the V-I characteristics of all the LED's on graph and take voltages corresponding to a constant current.

Now plot a graph between voltage V vs λ^{-1} and determine the slope of the line. It will give the value of (hc/e) (from eq. (6)). Now substitute the values of c (3×10^{8} m/s) and e (1.6×10^{-19} C) deduces the value of Planck's constant h.

OBSERVATIONS:

Table 1: For I-V characteristics of LEDs

Sr. No.	Red		Yellow		Green		Blue	
	Voltage V(volts)	Current I (µA)	Voltage V(volts)	Current I (µA)	Voltage V(volts)	Current I (µA)	Voltage V(volts)	Current I (µA)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Table 2: To calculate the Planck's constant (h) from I-V characteristics

Sr. No.	LED colour	Voltage V(volts)	Wavelength (λ) (nm)	Frequency f = c/λ	$h = \frac{eV\lambda}{c}$ (J.sec)
1.	Red		**660**		
2.	Yellow		**583**		
3.	Green		**565**		
4.	Blue		**430**		

Table 3: Results from graph voltage V vs λ^{-1}

Sr. No.	Voltage V(volts)	$\lambda^{-1} = (1/\lambda)\ (nm)^{-1}$	$\frac{hc}{e} = slope$	$h = \frac{e}{c}\ slope$ (J.s)
1.				
2.				
3.				
4.				

Calculation:

Conclusion:

Sign of the faculty: Date:

Review questions

1. Name the components of laser system.
2. Define stimulated & spontaneous emission with diagram.
3. Give the expression for the ratio of spontaneous and stimulated emission.
4. What are the Einstein's coefficients?
5. For a given laser diode, the wavelength of light emission is 1.55µm. What is its band gap in eV?
6. A laser source emits light of 0.621 µm and has an output of 35mW. Calculate how many photons are emitted per minute by this laser source?
7. According to Einstein's coefficients the probability of stimulated emission depends upon:
    a. Number of excited state atoms
    b. The energy density of simulating radiation
    c. Total number of energy levels
    d. Both (a) and (b)
8. What is the role of N_2 and He gas in CO_2 laser?
9. Find the ratio of population of the two energy states in a laser the transition between which is responsible for the emission of photons of wavelength 698.3×10^{-9}m. Assume the temperature 300K?
10. Explain energy level mechanism in Nd-YAG laser.

EXPERIMENT 8

Fiber Optics

Objective

To measure the numerical aperture of an optical fiber.

Apparatus

Diode laser source, Microscope objective, fiber Holders (2 nos), optical fiber, Base with rotational mount, Holders, bases and Screen

Theory

Numerical aperture is a basic descriptive characteristic of a specific fiber. It is represents the size or degree of openness of the input acceptance cone. Mathematically it is defined as the sine half angle of the acceptance cone.

Using Snell's law, the maximum angle within which light will be accepted into and guided through fiber is $NA = \text{Sin}(\theta_a) = (n_1^2 - n_2^2)^{1/2}$ ………………… (1)

where θ_a is the numerical aperture and n_1 and n_2 are the refractive indices of the core and the cladding. If the incident angle $\theta < \theta_a$, the ray undergoes multiple internal reflections at core and cladding interface and it is called the guided ray. If $\theta_a < \theta$, the ray undergoes only partial reflection at core cladding interface.

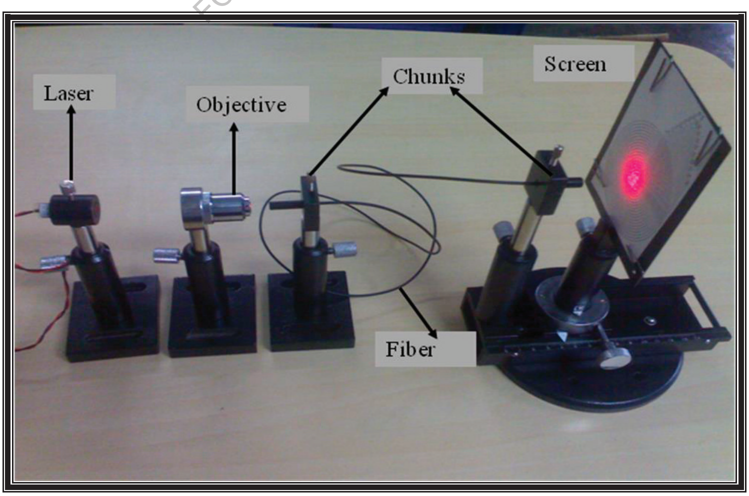


Fig.1 Experimental setup

In short length of straight fiber, ideally a ray launched at angle θ at the input end should come out at the same angle θ from output end. Therefore, the far field at the output end will also appear as a cone of semi angle θ_a emanating from the fiber end.

Procedure

1. Mount Laser source, objective and detector on the respective holders.
2. Mount both the ends of the optical fiber on the fiber holders.
3. Align the different objects as per the setup shown below.
4. Couple the light from the laser source onto one of the fiber ends using a microscopic objective (provided with the kit).
5. Place the screen (sheet having circular markings) at some distance from the output end of the fiber such that it is perpendicular to the axis of the fiber. Now move the screen towards or away from the output end of the fiber such that circular beam emanating from the fiber end covers the (1st or 2nd or 3rd) circle on the screen.
6. Measure the distance between the output end of optical fiber and screen. Let this be L. also measure the diameter of the circular spot formed on the screen. (Diameters are mentioned in mm). Let it be D.

7. Use the formula

$$NA = \sin\theta = \sin\left[\tan^{-1}\left(\frac{D}{2L}\right)\right] \quad \ldots\ldots\ldots.. (2)$$

Precautions

1. Mounting and coupling should be carefully done.
2. Care should be taken so that laser light should not directly fall into the eye.
3. As far as possible, experiment should be conducted in dark room environment.

Observations

Fiber –I: Single Mode (bare)

Circle No.	Diameter of Circle D (*mm*)	Dist. Between end of the Fiber and Screen L (*mm*)	D/2L	$\tan^{-1}\left(\frac{D}{2L}\right)$	NA	Average NA
1						
2						
3						
4						
5						

Fiber –II: Multi Mode

Circle No.	Diameter of Circle D (*mm*)	Dist. Between end of the Fiber and Screen L (*mm*)	D/2L	$\tan^{-1}\left(\frac{D}{2L}\right)$	NA	Average NA
1						
2						
3						
4						
5						

Conclusions

1. NA of given optical fiber – I = ______________________
2. NA of given optical fiber – II = ______________________

Calculation:

Conclusion:

Sign of the faculty: Date:

Review questions

1. What is the carrier in fiber optics communication system?
2. Discuss the principle of propagation of signals along optical fiber.
3. Discuss the advantage of optical fiber communication system over the conventional coaxial communication system.
4. Define acceptance angle & Numerical aperture of an optical fiber.
5. List four differences between single mode and multimode fiber.
6. In step index fiber, relative index difference is 2 % and cladding refractive index is 1.40 .Find (a) core refractive index (b) critical angle (c) NA (d) acceptance angle
7. Calculate the NA, the acceptance angle of the fiber having $n_1 = 1.48$ and $n_2 = 1.43$.
8. State the differences between step Index fiber and graded Index fiber?
9. A glass clad fiber is made with core glass of refractive index 1.5 and the cladding is doped to give a fractional index difference of 0.0005. Find the cladding index, the critical internal reflection angle, the external critical acceptance angle and the numerical aperture.
10. List any five applications of optical fiber cable.

EXPERIMENT 09

Hall Effect

Objective

Measure the Hall voltage, Carrier density, Hall coefficient and mobility of a given semiconductor material.

Apparatus

Gauss meter, Hall probe, Hall Effect set-up, Electromagnet, Constant current power supply etc.

Theory

If an electric current flows through a conductor in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor. This is most evident in a thin flat conductor as illustrated. A buildup of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall Effect after E. H. Hall who discovered it in 1879.

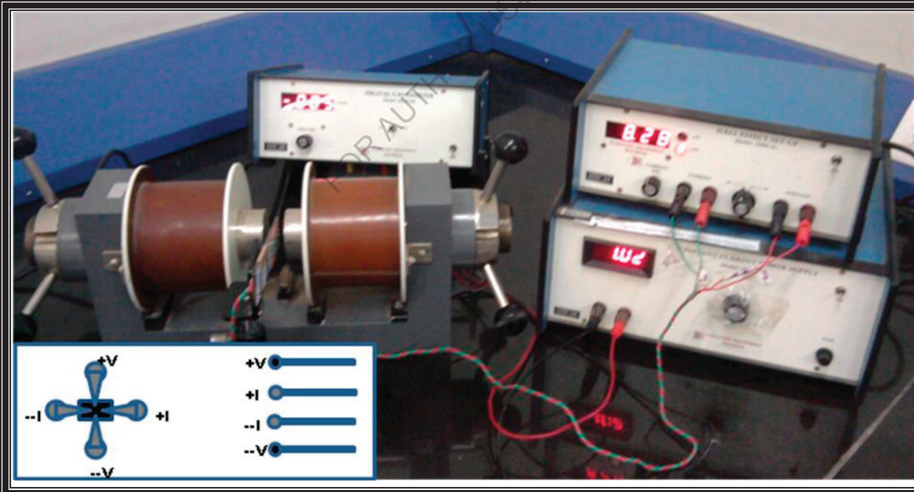


Fig. 1 Experimental Setup

Note that the direction of the current I in the diagram is that of conventional current, so that the motion of electrons is in the opposite direction. That further confuses all the "right-hand rule" manipulations you have to go through to get the direction of the forces.

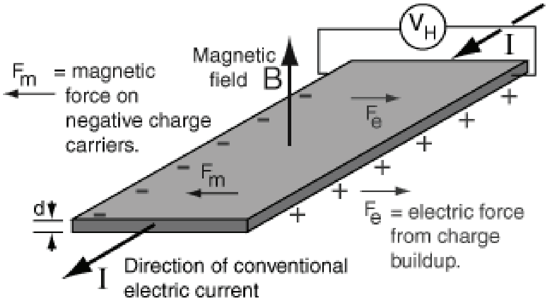


Fig.2 Production of Hall voltage

Procedure

1. Take Constant Current Power Supply & set the Current Adjust potentiometer at fully anticlockwise position. Connect electromagnet with Constant Current power supply such that two coils of electromagnet is in series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
2. Keep the Poles of electromagnet at some distance of 10mm.
3. Take Gauss & Tesla meter from the set of Hall Effect Trainer.
4. Connect InAs probe and switch on the Gauss & Tesla meter.
5. Adjust zero reading on display by Zero Adjust potentiometer and keep ready for measurement.
6. Now take measurement unit and set the switch position as follows
   a. Probe current potentiometer at minimum position.
   b. Probe Current/Hall voltage switch at probe current position.
7. Connect Hall Probe in given probe socket.
8. Switch on the Constant Current Power supply and set some low value of current.
9. Switch on the Measurement unit and increase probe current by probe current potentiometer and fix it at 5mA.
10. Select the Hall voltage/Probe current display for Hall voltage measurement.
11. There may be some voltage reading even outside the magnetic field. This is due to imperfect arrangement of the four contact of the hall probe and generally known as the "Zero field potential. In all cases, this error should be subtracted from the hall voltage reading as we consider it as a reference.
12. Now place the Hall probe between magnetic poles using stand such that the magnetic and electric field should be perpendicular to each other.
13. Due to this arrangement a force is generated in semiconductor, therefore a potential difference is developed in semiconductor wafer, which is perpendicular of both field (magnetic and electric). This potential difference is called Hall voltage.
14. You can measure & record this potential difference on the display.
15. Measure Hall voltage for both sides of probe.
16. Subtract Zero field potential and take the mean of both sides Hall voltages readings. This is Hall voltage V_H.
17. Calculate the other quantities by using the V_H in given equations.

Precautions

1. Handle the apparatus carefully.
2. The Hall probe should be placed between the pole pieces such that maximum Hall voltage is generated
3. Always increase or decrease the current gradually and switch on or off the power supply at the zero current position.

Observations

Probe Current (mA)	Magnetic Field (Gauss)	Zero field Potential (offset voltage)	Hall voltage for one side of the probe With offset voltage	Hall Voltage for Second side with offset voltage	Hall voltage for one side Without offset voltage (V^+)	Hall voltage for Second side Without offset (V^-)	Mean voltage (V_H)
I (*mA*)	B (Gauss)	V_0 (*mV*)	V_H^+ (*mV*)	V_H^- (*mV*)	$V_H^+ - V_0$ (*mV*)	$V_H^- - V_0$ (*mV*)	$(V^+ + V^-)/2$ (*mV*)

Calculations

1. Calculate the value of Hall coefficient using the formula $R_H = \left(\frac{V_H t}{IB}\right)$

   Where, t = thickness (= 5 x 10^{-2} *cm*)

2. Calculate the carrier charge density using the formula $n = \left(1/eR_H \right)$
3. Calculate the carrier mobility using the formula $\mu = R_H \sigma$

   Where, σ = electrical conductivity = 0.167 Ω^{-1} cm^{-1}

Results

1. Hall voltage (V_H) = ____________ *mV*
2. Carrier density (n_e) = ______________ $/m^3$
3. Hall coefficient (R_H) = ______________ $m^3\ C^{-1}$
4. Mobility (μ) = _____________ $m^2\ V^{-1}\ s^{-1}$

Calculation:

Conclusion:

Sign of the faculty: Date:

Review questions

1. Define mobility of electrons and holes. How are these two related to electrical conductivity of a semiconductor?
2. What is the order of energy gap in a conductor, insulator and semiconductor?
3. What is Fermi energy and Fermi level?
4. What is the conductivity of a semiconductor at Zero Kelvin?
5. What is Hall effect?
6. A p-type Ge has a donor density of 10^{23}per m^3. It is used in Hall effect experiment in which a magnetic field of $0.5Wb/m^2$ is used and current of $300Am^{-2}$ is passed. If the thickness of the Ge is 4mm find the Hall voltage developed.
7. The conductivity and the Hall coefficient of a n-type silicon specimen are 11.2 Ω^{-1} m^{-1} and $1.25x10^{-13}m^3C^{-1}$ respectively. Calculate the charge carrier density and electron mobility.
8. The Hall coefficient (R_H) of a semiconductor is 3.22 x 10^{-4} m^3 C^{-1}. Its resistivity is 9 x10^{-3} Ωm. Calculate the mobility and carrier concentration of the carriers.
9. The Hall coefficient of a specimen of doped silicon is found to be $3.66x10^{-4}m^3C^{-1}$. The resistivity of the specimen is $8.93x10^{-3}$ Ωm. Find the mobility and density of the charge carrier.
10. What are the important applications of Hall Effect?

EXPERIMENT 10

Measurement of Surface area to volume ratio

Objective

To understand how the change in the properties of materials takes place by decreasing its size at nano-scale.

Apparatus

Different size wooden pieces, Scale – meter, cm , Verneir callipers , Thread, etc.

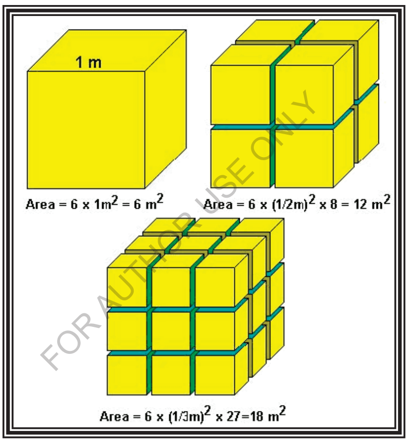


Fig. 1 Total surface area increases as you cut the block into smaller pieces, but the total volume stays constant

What is Nano Science?

Way back in 1959, a physicist named Richard Feynman shared his vision of what very small things would look like and how they would behave. In a speech at the California Institute of Technology titled "There's Plenty of Room at the Bottom," Feynman gave the first hint about what we now know as "nanoscience" : "The principles of physics, as far as I can see, do not speak against the possibility of

maneuvering things atom by atom." More generally, nanoscience is the study of the behavior of objects at a very small scale, roughly 1 to 100 nanometers (nm). One nanometer is one billionth of a meter, or the length of 10 hydrogen atoms lined up. Nanosized structures include the smallest of human-made devices and the largest molecules of living systems.

The prefix 'nano' is derived from the Greek word 'nanos' which means 'dwarf' or 'dwarfish'. It refers to the billionth part, i.e. 10-9 = 0.000000001. One nanometer is equivalent to one billionth of a meter or one thousandth of a micrometer. The functional properties of a particular material are dependent, in the case of tiny extensions, on the dimensions. For example, properties such as hardness, electrical conductivity, color or chemical reactivity of minuscule particles of any material are directly dependent on the diameter of the particle.

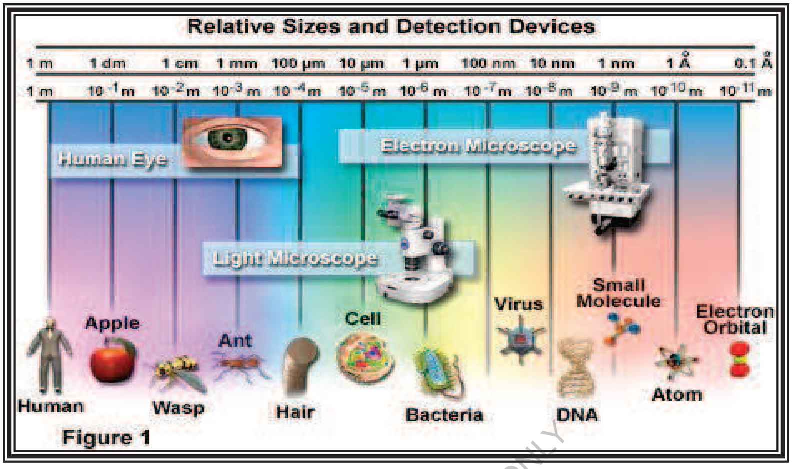


Fig.2 Size variation from one meter to one angstrom

What is the Big Deal About Nanoscience?

You might ask, "What is the big deal with nanoscience? Isn't it just a bunch of really small things?" It is, in fact, a bunch of small things. But it is a whole lot more. What makes the science at the nanoscale special is that at such a small scale, while all physical laws affect the behavior of matter, different laws dominate over those that we experience in our everyday lives. For example, the element gold (Au) as we are used to seeing it has a nice yellowish-brown color to it—the color we know as "gold." However, if you had only 100 gold atoms arranged in a cube, this block of gold would look very different—its color would be much more red. Color is just one property (optical) that is different at the nanoscale. Other properties, such a flexibility/strength (mechanical) and conductivity (electrical) are often very different at the nanoscale as well.

Why is Large Surface Area Important?

The large surface area to volume ratio of nanoparticles opens many possibilities for creating new materials and facilitating chemical processes. In conventional materials, most of the atoms are not at a surface; they form the bulk of the material. In nanomaterials, this bulk does not exist. Indeed, nanotechnology is often concerned with single layers of atoms on surfaces. Materials with this property are unique. For example, they can serve as very potent catalysts or be applied in thin films to serve as thermal barriers or to improve wear resistance of materials.

Observation

Part: - I

Sr. No.	Length (m)	Width (m)	Thickness (m)	surface area (m^2)	volume (m^3)	surface area/volume (m^{-1})
1						
2						
3						
4						
5						

Part: - II

Sr. No.	Length (m)	Width (m)	Thickness (m)	surface area (m^2)	volume (m^3)	surface area/volume (m^{-1})
1						
2						
3						
4						
5						

Calculation:

Conclusion:

Sign of the faculty: Date:

Review questions

1. How small is a nanometer, compared with a hair, a blood cell, a virus, or an atom?
2. Why are properties of nanoscale objects sometimes different than those of the same materials at the bulk scale?
3. How do we see and move things that are very small?
4. What are some of the ways that the discovery of a new technology can impact our lives?
5. Give a short explanation of why the nanoscale is “special.”
6. Name one example of a nanoscale structure and describe its interesting properties.

APPENDIX

Units and Physical Constants

Fundamental units:

S.No.	Physical Quantity	S.I.Unit
1.	Length	Meter
2.	Mass	Kilogram
3.	Time	Second
4.	Electric Current	Ampere
5.	Temperature	Kelvin
6.	Luminous Intensity	Candela

Derived units

S.No.	Physical Quantity	S.I. Unit
1.	Area	m^2
2.	Volume	m^3
3.	Density	Kgm^{-3}
4.	Velocity	ms^{-1}
5.	Angular velocity	rad s^{-1}
6.	Acceleration	ms^{-2}
7.	Force	Kgm^{-2}
8.	Work	Nm

9.	Power	Js^{-1} (watt)
10.	Rigidity Modulus	Nm^{-2}
11.	Magnetic Flux	Weber (volt second)
12.	Magnetic Intensity	Am^{-1}
13.	Magnetic moment	Am^{2}
14.	Magnetic Induction	Wb m^{-2}(tesla)
15.	Magnetic Permeability	Hm^{-1}
16.	Mag. Susceptibility	$Kg^{-1}\,m^{3}$
17.	Charge	C (Coulomb)
18.	Resistance	Ohm
19.	Inductance	H
20.	Capacitance	F (Farad)

Physical constants

Physical constant	**Substance**	**Value**
Density	Water	1000 kgm^{-3}
	Kerosene	830 kgm^{-3}
	Castor Oil	970 kgm^{-3}
	Glycerin	1260 kgm^{-3}
Refractive Index	Crown Glass	1.5
	Flint Glass	1.56
	Dense Crown Glass	1.620
	Dense Flint Glass	1.650
Rigidity Modulus	Aluminum	$2.5\times10^{10}Nm^{-2}$
	Brass	$3.5\times10^{10}Nm^{-2}$
	Cast Iron	$5.0\times10^{10}Nm^{-2}$
	Wrought Iron	$8.0\times10^{10}Nm^{-2}$
	Steel(cast)	$7.6\times10^{10}Nm^{-2}$
	Steel (mild)	$8.9\times10^{10}Nm^{-2}$
Compressibility	Ethyl alcohol	$76\times10^{-11}m^2/N$
	Methyl alcohol	$10^3\times10^{-11}m^2/N$
	Benzene	$91\times10^{-11}m^2/N$
	Kerosene	$75\times10^{-11}m^2/N$
	Castor oil	$47\times10^{-11}m^2/N$

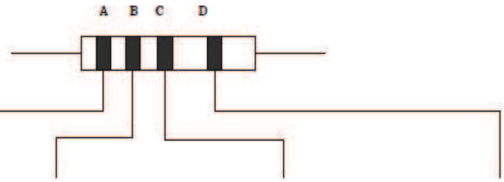
Prefixes

yotta	Y	10^{24}	giga	G	10^{9}	deci	d	10^{-1}	pico	p	10^{-12}
zetta	Z	10^{21}	mega	M	10^{6}	centi	c	10^{-2}	femto	f	10^{-15}
exa	E	10^{18}	kilo	k	10^{3}	milli	m	10^{-3}	atto	a	10^{-18}
peta	P	10^{15}	hecto	h	10^{2}	micro	μ	10^{-6}	zepto	z	10^{-21}
tera	T	10^{12}	deca	da	10	nano	n	10^{-9}	yocto	y	10^{-24}

Physical constants

Name	Symbol	Value	Unit
Number π	π	3.14159265358979323846	
Number e	e	2.71828182845904523536	
Euler's constant	$\gamma = \lim_{n\to\infty} \left(\sum_{k=1}^{n} 1/k - \ln(n) \right) = 0.5772156649$		
Elementary charge	e	$1.60217733 \cdot 10^{-19}$	C
Gravitational constant	G, κ	$6.67259 \cdot 10^{-11}$	$\mathrm{m^3kg^{-1}s^{-2}}$
Fine-structure constant	$\alpha = e^2/2hc\varepsilon_0$	$\approx 1/137$	
Speed of light in vacuum	c	$2.99792458 \cdot 10^{8}$	m/s (def)
Permittivity of the vacuum	ε_0	$8.854187 \cdot 10^{-12}$	F/m
Permeability of the vacuum	μ_0	$4\pi \cdot 10^{-7}$	H/m
$(4\pi\varepsilon_0)^{-1}$		$8.9876 \cdot 10^{9}$	$\mathrm{Nm^2C^{-2}}$
Planck's constant	h	$6.6260755 \cdot 10^{-34}$	Js
Dirac's constant	$\hbar = h/2\pi$	$1.0545727 \cdot 10^{-34}$	Js
Bohr magneton	$\mu_{\mathrm{B}} = e\hbar/2m_{\mathrm{e}}$	$9.2741 \cdot 10^{-24}$	$\mathrm{Am^2}$
Bohr radius	a_0	0.52918	Å
Rydberg's constant	Ry	13.595	eV
Electron Compton wavelength	$\lambda_{\mathrm{Ce}} = h/m_{\mathrm{e}}c$	$2.2463 \cdot 10^{-12}$	m
Proton Compton wavelength	$\lambda_{\mathrm{Cp}} = h/m_{\mathrm{p}}c$	$1.3214 \cdot 10^{-15}$	m
Reduced mass of the H-atom	μ_{H}	$9.1045755 \cdot 10^{-31}$	kg
Stefan-Boltzmann's constant	σ	$5.67032 \cdot 10^{-8}$	$\mathrm{Wm^{-2}K^{-4}}$
Wien's constant	k_{W}	$2.8978 \cdot 10^{-3}$	mK
Molar gasconstant	R	8.31441	$\mathrm{J{\cdot}mol^{-1}{\cdot}K^{-1}}$
Avogadro's constant	N_{A}	$6.0221367 \cdot 10^{23}$	$\mathrm{mol^{-1}}$
Boltzmann's constant	$k = R/N_{\mathrm{A}}$	$1.380658 \cdot 10^{-23}$	J/K
Electron mass	m_{e}	$9.1093897 \cdot 10^{-31}$	kg
Proton mass	m_{p}	$1.6726231 \cdot 10^{-27}$	kg
Neutron mass	m_{n}	$1.674954 \cdot 10^{-27}$	kg
Elementary mass unit	$m_{\mathrm{u}} = \frac{1}{12}m({}^{12}_{6}\mathrm{C})$	$1.6605656 \cdot 10^{-27}$	kg
Nuclear magneton	μ_{N}	$5.0508 \cdot 10^{-27}$	J/T
Diameter of the Sun	$D_\odot$	$1392 \cdot 10^{6}$	m
Mass of the Sun	$M_\odot$	$1.989 \cdot 10^{30}$	kg
Rotational period of the Sun	$T_\odot$	25.38	days
Radius of Earth	R_{A}	$6.378 \cdot 10^{6}$	m
Mass of Earth	M_{A}	$5.976 \cdot 10^{24}$	kg
Rotational period of Earth	T_{A}	23.96	hours
Earth orbital period	Tropical year	365.24219879	days
Astronomical unit	AU	$1.4959787066 \cdot 10^{11}$	m
Light year	lj	$9.4605 \cdot 10^{15}$	m
Parsec	pc	$3.0857 \cdot 10^{16}$	m
Hubble constant	H	$\approx (75 \pm 25)$	$\mathrm{km{\cdot}s^{-1}{\cdot}Mpc^{-1}}$

Resistor Color Code



A: FIRST BAND
1ST SIGNIFICANT FIGURE

COLOR	DIGIT
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

B: SECOND BAND
2ST SIGNIFICANT FIGURE

COLOR	DIGIT
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

C: THIRD BAND
MULTIPLIER

COLOR	DIGIT
SILVER	-2
GOLD	-1
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

D: FOURTH BAND
TOLERANCE

COLOR	DIGIT
WITHOUT	20 %
SILVER	10 %
GOLD	5 %
RED	2 %
BROWN	1 %

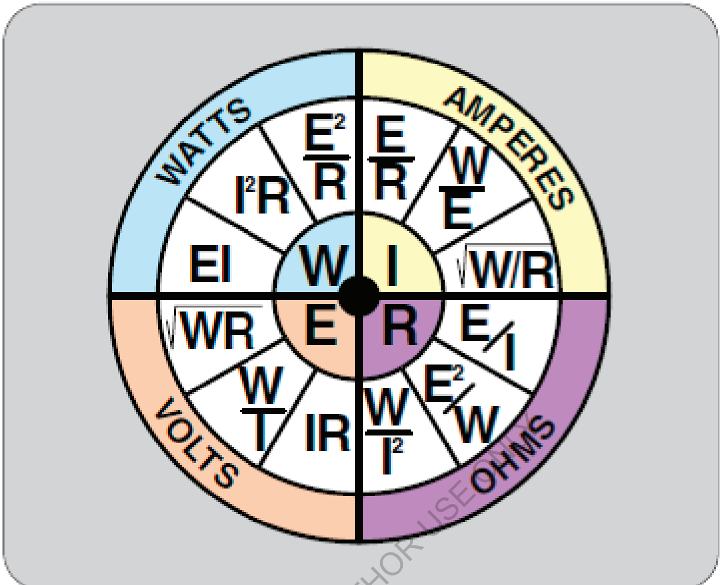
EXAMPLES

YELLOW	VIOLET	BROWN	SILVER		BROWN	RED	ORANGE	GOLD	
4	7	0	10 %	=470, 10%	1	2	000	5 %	=12KΩ, 5%

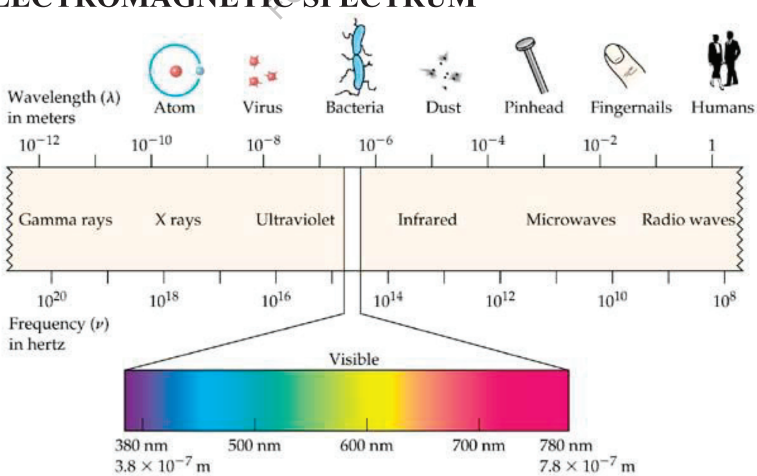
Electrical conductivity and concentration of electrons in some selected metals

Metal	*Number of valence electrons (Z)*	*Concentration of electrons in $10^{28}/m^3$*	*Electrical conductivity at 100 K in $W^{-1}\,m^{-1}$*	*Electrical conductivity at T = 300K*
Copper	1	8.47	2.9×10^8	6.5×10^7
Lead	4	13.2	1.5×10^8	5.2×10^6
Zinc	2	13.2	6.2×10^8	1.8×10^7
Gold	1	5.90	1.6×10^8	5.0×10^7
Aluminium	3	18.1	2.1×10^8	4.0×10^7
Cadmium	2	9.27	4.3×10^8	1.5×10^7
Iron	2	17.0	8.0×10^8	1.1×10^7

VARIATIONS OF OHM'S LAW



ELECTROMAGNETIC SPECTRUM



BIBLIOGRAPHY

Here is a short list of references to books which may be useful for further reading in Physics or instrumentation relevant to the experiments. Also included are some references to books of general interest with regard to science and experimentation.

1. "Fundamentals of Physics", 6th Ed., D. Halliday, R. Resnick and J. Walker, John Wiley and Sons, Inc., New York, 2001.
2. Errors of Observations and their treatment, J. Topping, 3rd Ed. Chapman and Hall ltd. London.
3. "Optics", A Ghatak, Tata-McGraw Hill, New Delhi, 1992.
4. “Experiments in Engineering Physics” S. Chand and Company Ltd, 1996.
5. “Engineering Physics” Abhijit Nayak, S. K Kataria and Sons, 2008.
6. Engg. Physics by G. Vijayakumari, Vikas Publishing house Pvt. Ltd, 2008.
7. Solid State Physics by C. Kittle

❖ **Reference Links/ e-material:**

1. http://www.nptel.iitm.ac.in/courses/Webcourse-contents/IIT %20Guwahati/engg_physics/index_cont.htm
2. http://ncert.nic.in/html/learning_basket.htm
3. http://science.howstuffworks.com/laser1.htm
4. http://physics-animations.com/Physics/English/optics.htm
5. http://physics-animations.com/Physics/English/waves.htm
6. http://www.epsrc.ac.uk
7. http://www.pitt.edu/~poole/physics.html#light
8. http://de.physnet.net/PhysNet/optics.html


More Books!
yes
I want morebooks!