BAS 151/ 251: ENGINEERING PHYSICS LAB LABORATORY

GENERAL INSTRUCTIONS:

1. Students are instructed to come to Environmental Engineering laboratory on time. Late comers are not entertained in the lab.
2. Students should be punctual to the lab. If not, conducted experiments will not be repeated.
3. Students are expected to come prepared at home with the experiments which are going to perform.
4. Students are instructed to display their identity cards and apron before entering into the lab.
5. Students are instructed not to bring mobile phones to the lab.
6. Any damage to glassware and equipment during the lab session is student’s responsibility and penalty or fine will be collected from the student. If such matter is not reported to lab instructor, the fine will be imposed on students of that group by whom an experiment is done.
7. Do not throw waste such as paper, filter papers etc. into the dustbin /sink.
8. Keep the water closed except when these utilities are needed.
9. Students should update the records and lab observation books session wise. Before leaving the lab the student should get his lab observation book signed by the faculty.
10. Students should submit the lab records 2/3 days in advance to the concerned faculty members in the staffroom for their correction and return.
11. Students should not move around the lab during the lab session.
12. If any emergency arises, the student should take the permission from faculty member concerned in written format.
13. The faculty members may suspend any student from the lab session on disciplinary grounds.
14. Never cook up the result by recording false observations or by making manipulated calculations.
15. All the data should be prettified with the relevant units in observation table
16. The calculation should be done with right unit system.
17. The graph are plotted very carefully. The X axis and Y axis should labeled with proper units. And scale should be mentioned o graph.
18. The block/Ray/circuit Diagram should be prepared and labeled correctly. It is made by pencil and use of geometry box.

SAFETY PRECAUTIONS:

1. While working in the laboratory suitable precautions should be observed to prevent accidents.
2. Always follow the experimental instructions strictly.
3. Use the fire extinguisher available in the lab in case of fire.
4. Use the first aid box in case of any accident/mishap.
5. Never work in the laboratory unless a demonstrator or teaching assistant in present.
6. All the instruments must be carefully handled.
7. Even after all precautions, still if accident occurs, do not panic and inform the instructor at once and act as per his suggestions.
8. Never touch electrical switches if it is faulty.

INDEX OF EXPERIMENTS

Sl.	Object of Experiment
1	To determine the wavelength of sodium light by Newton's Ring.
2	To determine the coefficient of Viscosity of water by Poiseuille's method.
3	To determine the focal length of the combination of two lenses separated by a distance with the help of a Nodal Slide and to verify the formula $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$
4	To draw hysteresis curve (B – H CURVE) of a given sample of a ferromagnetic material in the form of thin iron wires (or cycle spokes) on a cathode ray oscilloscope (C.R.O.) using a solenoid and to determine retentivity, coercivity and hysteresis loss from it.
5	To determine the wavelength of prominent spectral lines of Mercury light by Plane Diffraction gratings.
6	To determine the resistance per unit length of Carry Foster's Bridges wire and the specific resistance of the given wire by comparing the resistance of wire with standard resistance.
7	To plot graph showing the variation of magnetic field with distance along the axis of a circular coil carrying current and evaluate from it the radius of the coil.
8	To verify Stefan's Law by electrical method
9	To determine the width of the forbidden energy gap in a semiconductor material using a PN junction diode.
10	To determine the frequency of A. C. Mains with the help of Sonometer.

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Aid to an Experimenter

(The students are advised to go through with it before performing any experiment)

How to Use a Log Table in the Experimental Calculations

Logarithm, which means a rule to shorten arithmetic, was developed about three hundred years ago by **Napier** and **Briggs**. Logarithms provide us with a means of simplifying many calculations : by means of them we can replace multiplication and division by addition and subtraction. It reduces the labour of many hours or day into few minutes. In physics practicals, a students is expected to make calculations by using logarithm tables. It has come to our knowledge that most of the students are unable to use log tables. To facilitate the correct way of the use of logarithm in practical calculations, a brief discussion about the use of log tables is given below :

There are two system of logarithms *viz*.:

(*i*) Natural Logarithm and

(*ii*) Common Logarithm .

(*i*) **Natural Logarithm :** Logarithms calculated to the base *e* are called natural logarithm or Napierian logarithms after its inventor, Napier. Natural logarithms are generally used in higher mathematics.

(*ii*) **Common Logarithm :** Logarithms calculated to the base '10' are commonly used in all arithmetical calculations involved in practical physics.

The logarithm of any number to a given base is the power or exponent to which the base must be raised in order to obtain that number.

For example, we know that 2 raised to power 3 is equal to 8, that is, $2^3 = 8$

In logarithm, this fact is stated as **"the logarithm of 8 to the base 2 is equal to 3"**, that is, $\log_2 8 = 3$

In general, if $a^x = N$, then $\log_a N = x$

The log tables used in the calculations are generally of common logarithm. The base 10 is normally not mentioned. **For example, log 18 mean log of 18 to the base 10.**

In physics and other applied science, in the formulae involving logarithmic function, the base to the logarithm is always '*e*'.

For making calculations with log table following formulae should be remembered

1. Product formula $\quad \log mn = \log m + \log n$
2. Quotient formula $\quad \log (m/n) = \log m - \log n$
3. Power formula $\quad \log m^n = n \log m$

Characteristic and Mantissa

Logarithm of a number consists of two parts :

(*i*) **Characteristic** is the integral (whole or natural number) part of a logarithm of a number. It may be positive or negative. When the characteristic is negative, it is expressed by putting a sign (–) bar over it.

(*ii*) **Mantissa** is the fractional (or decimal) part of the logarithm. The mantissa is always positive.

Determination of characteristic of a number

The characteristic of any number is determined by the position of the decimal point. **For number greater than one or equal to one, the characteristic is positive and is equal to one less than the number of digits to the left of the decimal point. For number less than one characteristic is negative and is equal to one more than the number of zeros to the right of decimal point.**

Examples : In a number, say 3598.267, there are four figures to the left of the decimal point. Therefore, its characteristic will be three **(one less than the digits to the left of decimal)**, that is, $4 - 1 = 3$. If we consider number 0.004502 then its characteristic is $\bar{3}$ (– **{number of zero to the right of decimal before start of any digit + one}**)

The characteristic of some numbers greater than one are given in tabular form as :

Number	5873*	1693.502	31*	0398.658	1.2468
Number of digits before decimal point	4	4	2	3(0 is meaning less)	1
Characteristic	3	3	1	2	0

Imagine decimal after last digit, read as 5873.0 *and* 31.0.

The characteristic of some number less than one are given in tabular form as :

Number	0.3980	0.00607	0.0008	0.059	0.00002357
Number of zero after decimal but before any digit	0	2	3	1	4
Characteristic = – [No.of zero + 1]	$\bar{1}$	$\bar{3}$	$\bar{4}$	$\bar{2}$	$\bar{5}$

Determination of a mantissa

Mantissa of a given number is always determined by log tables. The value of mantissa depends on the digits and their order, and is independent of the position of the decimal point. For example, the value of mantissa for log 125, log 1.25 and log 0.0125 are same. **For finding the value of mantissa, we consider the finite digits (digits other than zero) and zeros between the finite digits. Zeros toward extremely left and extremely right sides of a number are ignored.** For example in numbers 49800 and 0.00498, zeros towards extremely left side and toward extremely right side have no significance. However, in 2308 and 2.308 zero in the middle has a great importance in finding out mantissa.

The logarithm tables give the mantissa only. They are usually meant for those numbers which contains four digits and if a number consists of more than four digits, it is rounded off to four digits, for example, 128932 should be considered as 1289 and 326884 as 3269. For finding mantissa of a number the log tables are consolidated in the following manner, (A sample of log table is given below)

Table I : Logarithms

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	2	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6

Suppose we have to find the log of 596.6. **For this we locate 59 in the extreme left column in the log table (Table-I), then move horizontally to column 6 and note the number. It is 7752. At the right end of the table mean differences are given for 1 to 9, which help in finding the log of fourth figure.** The fourth figure in the given number is 6, thus see the mean difference in front of 59 below the mean difference head 6 which is 4 here. Add it to the value obtained above, which gives the mantissa of 5966 as $7752 + 4 = 7756$. **Hence, the log of 596.6 is 2.7756.** Thus, we concluded that, the final log of a given number = Characteristic.mantissa. Here point (.) represents the decimal.

Note : Remember that mantissa is always positive whereas characteristic may be positive or negative. Therefore, the log of number having positive characteristic is written as 2.7756 and 1.7501 (log of number 56.25), but in case of negative characteristic (or log for number less than one); the log of a number is written as $\bar{3}.7679$ (log of number 0.00586) and not as –3.7679. If mantissa is negative make it positive by adding and subtracting one. For example, In –2.3122, the mantissa is negative. Hence, by adding and subtracting one it can be made positive as, $-2.3122 + 1 - 1 = -2 + (1 - 0.3122) - 1 = \bar{3}.6878$.

The process of locating characteristic and mantissa of a number and their final log can be understood more clearly from the following table.

Table II

Number for logarithm	Characteristic	Mantissa						Log (Characteristic. mantissa)*
		Digits			Log of first two digits bellow third (a)	Mean difference for fourth (b)	Total (a +b)	
		First two	Third	Fourth				
554.2	$3 - 1 = 2$	55	4	2	7435	2	7437	2.7437
5.6	$1 - 1 = 0$	56	0	0	7482	0	7482	0.7482
0.58347	$-(0 + 1) = \bar{1}$	58	3	5	7657	4	7661	$\bar{1}.7661$
0.0060	$-(2 + 1) = \bar{3}$	60	0	0	7782	0	7782	$\bar{3}.7782$
0.0005708	$-(3 + 1) = \bar{4}$	57	0	8	7559	6	7565	$\bar{4}.7565$
563693	$6 - 1 = 5$	56	3	7	7505	5	7510	5.7510

*Here point (.) represents decimal.

Antilogarithm

The number whose logarithm is x is called antilogarithm, for example, if $\log m = n$ then $m = \text{antilog}\, n$. It is therefore, clear that finding of logarithm and antilogarithm are mutually reverse process. After simplifying the values of log, taken for any given calculation, the corresponding antilog value is determined by the use of antilog tables as follows (A sample of antilog table is given below) :

Table-III

Antilogarithm

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7

For finding the antilogarithm of a number (say 3.5591) first consider only mantissa part (decimal part) of a number and ignore characteristic part, that is, consider 5591 only.

Now read the antilog table in a similar method as adopted for reading log table, that is, locate first two digits with decimal of mantissa (.55) in extreme left column of antilog table and then in this line (of

.55) move horizontally till the column headed by the third figure 9 is reached [for example, in horizontal line of .55 below the third digit 9, it is 3622 (table III)].

Now in the same horizontal line, find the mean difference below the fourth digit (that is, 1), which is 1. Add it to the previous number that is, 3622 + 1 = 3623.

Now place the decimal after first digit from left (that is, 3.623) and multiply it by 10 the power characteristic of given log with its sign (that is, $10^{\text{characteristic}}$). Therefore, 3.623 is multiplied by 10^3 is the required antilog, that is,

$$\text{antilog of } 3.5591 = 3.623 \times 10^3$$

Similarly,

$$\text{antilog of } 0.5591 = 3.623 \times 10^0$$

$$\text{antilog } \bar{3}.5591 = 3.623 \times 10^{-3}$$

Multiplication and Division : Multiplication of two and more numbers is affected by obtaining sum, and division by obtaining the difference of the logarithms of the numbers.

Uses of Log Tables in Various Types of Calculations

***Example* 1 :** *The logarithm of a number is* – 1.4771. *Find the characteristic and mantissa.*

***Solution* :** $-1.4771 = -1 + (-0.4771)$

The mantissa (or decimal part) is negative in this result, but mantissa is always positive to make it positive, we add and subtract 1.

Therefore,

$$-1.4771 = -1 + (1 - 0.4771) - 1$$
$$= -2 + 0.5229$$
$$= \bar{2}.5229$$

Hence the characteristic is $\bar{2}$ and mantissa is 0.5229.

***Example* 2 :** *Multiply* 359.28 *by* 0.000337.

***Solution* :** $\log(359.28 \times 0.000337) = \log 359.28 + \log 0.000337$

$$= 2.5555 + \bar{4}.5276$$
$$= \bar{1}.0831$$

(Explanation – the above sum is obtained by carrying 1 from the mantissa, which gives + 3 : then $3 + \bar{4} = \bar{1}$)

Taking antilog

$$\text{Antilog}(\bar{1}.0831) = 1.211 \times 10^{-1}$$
$$= 0.1211$$

***Example* 3 :** *Divide* 359.28 *by* 0.000337.

***Solution*:**

$$\log\left(\frac{359.28}{0.000337}\right) = \log 359.28 - \log 0.000337$$
$$= 2.5555 - \bar{4}.5276$$
$$= 6.0279.$$

(Explanation – in subtraction it is advisable to alter (mentally) the sign of the characteristic of the lower figures and add. Hence $\bar{4}$ becomes + 4)

Taking antilog

$$\text{Antilog}(6.0279) = 1.066 \times 10^6$$

***Example* 4 :** *Multiply* 0.04583 *by* 0.00345.

***Solution* :** $\log(0.00345 \times 0.04583) = \log 0.00345 + \log 0.04583$

$$= \bar{3}.5378 + \bar{2}.6612$$

$$= \bar{4}.1990$$

(Explanation – the sum of negative indices is 5 but 1 carried from the mantissa makes the sum to be $\bar{4}$)

$$\text{Antilog}(\bar{4}.1990) = 1.581 \times 10^{-4}$$

$$= \mathbf{0.000158.}$$

***Example* 5 :** *Divide* 0.04583 *by* 0.00345.

***Solution* :** $$\log\left(\frac{0.04583}{0.00345}\right) = \log 0.04583 - \log 0.00345$$

$$= \bar{2}.6612 - \bar{3}.5378$$

$$= 1.1234$$

(Explanation – by altering (mentally) the sign of the characteristic of the lower figure and adding. Thus, $\bar{3}$ becomes + 3)

$$\text{Antilog}(1.1234) = 1.328 \times 10^1$$

$$= \mathbf{13.28}$$

***Example* 6 :** *Divide* 0.2534 *by* 0.09072.

***Solution* :** $$\log\left(\frac{0.2534}{0.09072}\right) = \log 0.2534 - \log 0.09072$$

$$= \bar{1}.4038 - \bar{2}.9577$$

$$= 0.4461$$

$$\text{Antilog}(0.4461) = 2.793 \times 10^\circ = \mathbf{2.793}$$

***Example* 7 :** *Compute the following by using log and antilog tables :*

$$x = \frac{0.09 \times (38.23)^3 \times (41.3)^2 \times \sqrt{9.6} \times 10^6}{5 \times (0.00913)^{1/3} \times 10^{-3} \times 0.0135 \times (0.06)^4}$$

***Solution* :** First of all find the log of numerator (N^r) and denominator (D^r) by adding the log of individual number as follows :

log N^r

$$\log 0.09 = \bar{2}.9542$$

$$3\log 38.23 = 1.5824 \times 3 = 4.7472$$

$$2\log 41.3 = 1.6160 \times 2 = 3.2320$$

$$\tfrac{1}{2}\log 9.6 = 0.9823 \times \tfrac{1}{2} = 0.4911$$

$$6\log 10 = 1.0000 \times 6 = 6.000$$

$$\underline{13.4245}$$

log D^r

$$\log 5 = 0.6990$$

$$\log(0.000913)^{1/3}$$

$$\tfrac{1}{3} \times (\bar{4}.9605) = \bar{2}.9869$$

$$[(-4) \times \tfrac{1}{3} + 0.9605 \times \tfrac{1}{3}]$$

$$(-1.3333 + 0.3202)$$

$$(-1.0131 = \bar{2}.9869)$$

$$\log 10^{-3} = \bar{3}.0000$$

$$\log 0.0135 = \bar{2}.1303$$

$$\log(0.06)^4 = \bar{5}.1128$$

$$(4 \times \bar{2}.7782)$$

$$[4 \times (-2) + 4 \times .7782]$$

$$\overline{\overline{11}.9290}$$

Now, $\log x = \log N_r - \log D_r = 13.4245$

$$\begin{array}{r} 13.4245 \\ \overline{11}.9290 \\ \hline 23.4955 \end{array}$$

Now taking antilog of the log so obtained, we get

$$x = \text{Antilog}\ (23.4955) = \mathbf{3.130 \times 10^{23}}$$

***Example* 8 :** *Compute the following by the use of log and antilog tables :*

(*i*) $(0.4529)^{3.34}$, (*ii*) $(0.4529)^{-3.34}$

***Solution* :** (*i*) $(0.4529)^{3.34}$

Taking logarithm, we have

$$\begin{aligned} \log (0.4529)^{3.34} &= 3.34 \log 0.4529 \\ &= 3.34 \times \bar{1}.6560 \\ &= 3.34 \times (-1) + (3.34 \times 0.6560) \\ &= -3.34 + 2.1910 \\ &= -1.1490 \end{aligned}$$

(Since, mantissa is always positive to make it positive we odd and subtract 1, that is,

$-1 - 1 + (1 - 0.1490) = -2 + 0.8510 = \bar{2}.8510$)

$\therefore \log (0.4529)^{3.34} = \bar{2}.8510$

Taking antilog

Antilog $(\bar{2}.8510) = \mathbf{7.096 \times 10^{-2}}$

(*ii*) $(0.4529)^{-3.34}$

Taking logarithm, we get

$$\begin{aligned} \log (0.4529)^{-3.34} &= -3.34 \log 0.4529 \\ &= (-3.34) \times \bar{1}.6560 \\ &= (-3.34)(-1) + (-3.34 \times 0.6560) \\ &= 3.34 - 2.1910 \\ &= \mathbf{1.1490} \end{aligned}$$

$\therefore \log (0.4529)^{-3.34} = 1.1490$

Taking antilog

Antilog $(1.1490) = 1.409 \times 10^1 = \mathbf{14.09}$

***Example* 9 :** *Compute the following by the use of log and antilog tables.*

$$x = \frac{(92.4)^2 \times 3.9 \times 0.45 + \sqrt{132.68} \times 10^5 \times (0.02)^{-2}}{32.356 \times (9.8)^4 \times (0.06)^{1/5} - (1.3958)^3 \times (58.4)^{1/3}}$$

***Solution* :** The above equation can be written in the form

$$x = \frac{A + B}{C - D}$$

Where $A = (92.4)^2 \times 3.9 \times 0.045$, $B = (132.68)^{1/2} \times 10^5 \times (0.02)^{-2}$

$C = 32.356 \times (9.8)^4 \times (0.06)^{1/5}$ and $D = (1.3958)^3 \times (58.4)^{1/3}$

To solve the actual problem, we first find out the values of A, B, C and D separately by using log and antilog tables as follows :

log A

$2 \log 92.4$

$(2 \times 1.9657) = 3.9314$

$\log 3.9 = 0.5911$

$\log 0.045 = \bar{2}.6532$

$\underline{3.1757}$

or $\log A = 3.1757$

Thus, $A = \text{Antilog}\,(3.1757)$

or $\mathbf{A = 1.498 \times 10^3}$

log B

$\frac{1}{2} \log 132.68$

$(\frac{1}{2} \times 2.1229) = 1.0614$

$\log 10^5 = 5.0000$

$-2 \log 0.02$

$[(-2) \times \bar{2}.3010]$

$[(-2) \times (-2) + (-2) \times 0.3010]$

$[4 + (-0.6020)]$

$[4 + \bar{1}.3980] = 3.3980$

$\underline{9.4594}$

or $\log B = 9.4594$

Thus, $B = \text{Antilog}\,(9.4594)$

or $\mathbf{B = 2.880 \times 10^9}$

log C

$\log 32.356 = 1.5100$

$4 \log 9.8$

$(4 \times 0.9912) = 3.9648$

$1/5 \log 0.06$

$(0.2 \times \bar{2}.7782)$

$[0.2 \times (-2) + (0.2) \times 0.7782]$

$(-0.4 + 0.1556)$

$(-0.2444 = \bar{1}.7556) = \bar{1}.7556$

$\underline{5.2304}$

or $\log C = 5.2304$

Thus, $C = \text{Antilog}\,(5.2304)$

or $C = 1.700 \times 10^5$

log D

$3 \log 1.3958$

$(3 \times 0.1449) = 0.4347$

$\frac{1}{3} \log 58.4$

$(\frac{1}{3} \times 1.7664) = 0.5888$

$\underline{1.0235}$

or $\log D = 1.0235$

Thus, $D = \text{Antilog}\,(1.0235)$

or $D = 1.055 \times 10^1$

$$\text{Hence,}\quad x = \frac{A+B}{C-D} = \frac{1.498 \times 10^3 + 2.880 \times 10^9}{1.700 \times 10^5 - 1.055 \times 10^1}$$

$$= \frac{1.498 \times 10^3 + 2880000.0 \times 10^3}{1.700 \times 10^5 - 0.0001055 \times 10^5}$$

$$= \frac{2.8800 \times 10^9}{1.6998 \times 10^5}$$

or $\mathbf{x = 1.694 \times 10^4}$

How to Plot a Graph with the Experimental Observations

Now-a-days we see extensively in newspapers, magazines, advertisements and other form of media (like television, radio, internet etc.) reports of companies, Government pamphlets, etc. a lot of valuable informations pertaining to statistical data in the form of various graphs for understanding them easily and in grasping them quickly. In fact it has become a powerful tool in all branches of science, engineering, medical and technology.

In scientific language, pictorial representation of the experimental observations is called **graph.** A graph can be drawn in any two interdependent quantities. A graph is a line (straight or curved) showing the relation between two variable quantities of which one varies as a result of the change in the other. It not only represents the relation between two variable quantities but also unable us :

1. To verify certain laws
2. To calibrate certain instruments and to determine their true readings.
3. To find mean values from a large number of observations.
4. To determine certain quantities that are not actually observed during an experiment, by the method of interpolation and extrapolation.

A graph is generally plotted on a graph paper by taking independent variable along X-axis (horizontal line at the bottom of the graph paper) and dependent variables along Y-axis (at right angle to X-axis). The point of intersection of the two axes is, generally called origin. If some of the values of one of the two variables or both the variables are negative, the origin is suitably shifted so that the negative values of independent variable are taken towards the left of the origin and the negative values of dependent quantity are taken below the or gin.

The choice of scales is arbitrary and should be made on the basis of convenience and completeness of representation. To select the proper scale find the spread of both the variables (that is, the difference between observed minimum and maximum values of that variable). As an example, let us suppose to plot a graph between ammeter reading I and error in ammeter reading $I-I'$ in a calibration of an ammeter by means of a potentiometer experiment (expt. no. 9). Suppose their measured values are as follows :

Ammeter reading I (amp)	0.1	0.2	0.3	0.4	0.5	0.6
Error in ammeter reading $I'-I$ (amp)	0.014	0.042	0.030	0.024	0.63	0.070

Then, the spread of I is $S_x = 0.6 - 0.1 = 0.5$ amp and that of error $(I' - I)$ in ammeter reading is $S_y = 0.070 - 0.014 = 0.056$ amp

Suppose on the given graph paper, the number of big squares along X-axis are six ($N_x = 6$) and along Y-axis these are eight ($N_y = 8$). Now find the ratios S_x/N and S_y/N_y and convert their values to just a big convenient value such as 0.1, 0.2, 0.3 and 0.01, 0.02, 0.03 ... (in a regular interval, not with an arbitrary interval such as 0.1, 0.3, 0.4, 0.6 etc.). Now consider the scale along X-axis and Y-axis according to the values so obtained. In the above example the scale on X-axis is, 1 big square = 0.1 amp. and on Y-axis as, 1 big square = 0.01 amp.

The experimental values obtained are represented by means of sharp dots with small circle drawn about them. A smooth curve drawn through these points as nearly as possible (so that very few points are far from the curve such that there are as many points on one side of it as on the other) will graphically represent the observations. A title for the graph drawn should always be given and also the coordinate along each axis should be written with a statement of the quantity plotted and the unit in which it is expressed (As shown in fig. 1).

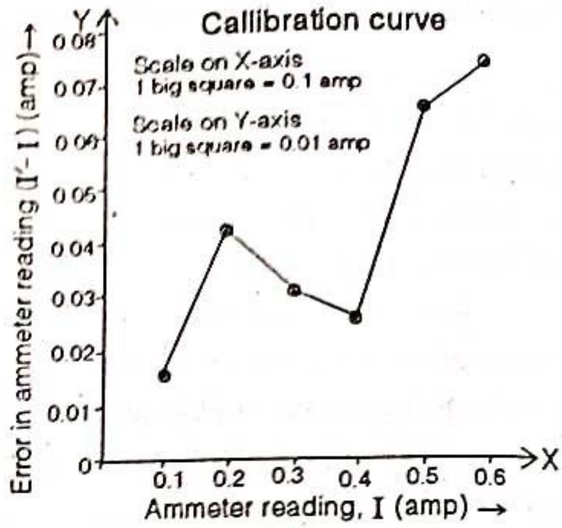


Fig. 1

Student need not to be disappointed if his points of observations do not fall on the actual line or curve. They are the result of, and in a way, a measure of the amount of unremovable errors and his honesty.

How to Calculate Errors Associated with Observations

Nearly all the experimental measurements, direct or indirect, are in some way or other approximate because every instrument has a limit (which is numerically equal to its least count) below which accurate measurements cannot be made by it. In spite of it, the accuracy of a single observation depends on the skill and care with which the observation is taken. A measurement in which all kinds of error and mistakes are minimised, is called accurate measurement. The accuracy in the results can be increased by taking more care in making the measurement as well as by using more refined instruments.

The most common errors expected to be occurred in the experimental observations are classified as **constant, systematic,** and **random (or accidental).**

Constant errors are those which affect the result of a series of experiment by the same magnitude (for example, by the use of a scale in which the graduation is faulty). Such type of errors can be detected by making physical measurements with different methods.

Systematic errors are those which occur according to some rule and during an experiment a factor operates in such a way as to make the observed value always higher or lower than the true value. These types of errors can be eliminated once their source is detected, and rule governing them is known. In these cases, the experiment is repeated under different conditions. If variation of conditions does not alter the result, one may set his mind at rest that there is no systematic error.

Errors arising due to non-controllable conditions affecting the observer, the measuring device and the quantity measured, are called random or accidental errors. In the presence of random error the variation in the observations are governed by chance. The effect of random error may be minimised by taking a large number of measurements of a given quantity and using the mean of these values in any computations.

Propagation of error is particularly important in connection with iterative processes and computations where each value depends on its predecessor. The following rules are adopted in the propagation of errors.

(*i*) **If two measured quantities are to be added or subtracted from each other, then the error in the result will always be sum of the errors in their measurements.**

(*ii*) **If two measured quantities are to be divide or multiplied together, then the fractional error ($\Delta R/R$) in the result R is the sum of fraction errors ($\Delta x/x$ and $\Delta y/y$) in the measurements of x and y.**

(*iii*) **If the result R is the some power n of the measured quantity x, then the fractional error in R is n times the fractional error in x.**

It is desirable to calculate the following maximum errors in case of all experimental findings :

1. Percentage permissible error : Let us suppose in any experiment we measure four physical quantities a, b, c and d by different instruments and we have to determine a physical quantity P which is related to a, b, c and d as,

$$P = \frac{2\pi k\, a^x\, b^y}{c^m\, d^n}$$

where K is constant and x, y, m and n are powers of quantities a, b, c and d respectively.

To find the permissible error in P we take logarithm of both sides as,

$$\log P = \log 2 + \log \pi + \log k + x \log a + y \log b - m \log c - n \log d$$

Partially differentiating above expression, we get

$$\frac{\delta P}{P} = 0 + 0 + 0 + x\frac{\delta a}{a} + y\frac{\delta b}{b} - m\frac{\delta c}{c} - n\frac{\delta d}{d}$$

Since 2, π and k are constants so there is no uncertainty in it. Here δa, δb, δc, δd represent the uncertainty in the measurements of a, b, c and d and are numerically equal to the least counts of the instruments used to determine the concerned quantity.

Since the error in many measurement may be positive (or higher than the actual value) or negative (or lower than the actual value), therefore, it is quite reasonable to consider the maximum possible theoretical error in P as,

$$\frac{\delta P}{P} = x\frac{\delta a}{a} + y\frac{\delta b}{b} - m\frac{\delta c}{c} - n\frac{\delta d}{d}$$

Hence the maximum possible percentage error in P is given by

$$\frac{\delta P}{P} \times 100 = \left(x\frac{\delta a}{a} + y\frac{\delta b}{b} + m\frac{\delta c}{c} + n\frac{\delta d}{d}\right) \times 100$$

As an example, consider the formula for the determination of coefficient of viscosity (η) of water (experiment no. 15) as,

$$\eta = \frac{\pi \rho r^4}{8l}\left(\frac{h}{Q}\right)$$

where π, ρ, 8 and g are constants and r, h, l and Q are to be measured.

The percentage permissible error in the measurement is given as,

$$\frac{\delta\eta}{\eta}\times 100=\left(u\frac{\delta r}{r}+\frac{\delta h}{h}+\frac{\delta l}{l}+\frac{\delta q}{q}\right)\times 100$$

Percentage errors : It is a usual practice to estimate the accuracy of the result of an experiment by comparison with the known standard results (if given) and expressing the deviation between them in the form of a percentage error. It is calculated by the relation given by

$$\text{Percentage error}=\frac{\text{Standard value}-\text{Experimental value}}{\text{Standard value}}\times 100$$

Important Points to be Followed Before Entering in the Laboratory

In order to make the best use of time in the laboratory, to avoid confusions and to obtain accurate results, it is necessary for the students to follow the following instructions :

Students should come to the laboratory along with one separate ordinary copy, practical note book and practical book with full preparation.

First of all ordinary copy is used to record the following points related with the experiment to be performed on that day.

Heading of the object, apparatus required, formula to be used for calculating the result alongwith the proper explanation of the symbols involved therein. Circuit diagram to be used for making connections in case of electricity and electronics experiments, observation tables and precautions to be taken while working with the apparatus. The procedure to be followed in performing the allotted experiment must be read many times with full concentration at home before coming to the lab. The theoretical background for the experiments should be thoroughly prepared for better understanding and viva-voce test. Any problem related with the procedure and apparatus must be removed with the consultation of the teacher concern before approaching to the apparatus for performing the experiment.

Now, deal with the apparatus carefully and when everything goes right follow the procedure of the experiment according to this book and note down the readings observed in the observation table(s) in the same ordinary copy. A systematic tabulation of observation is very essential. Take as much reading as you can, specially for quantities which appears with higher powers in the formula, which appears small and which are required for plotting a graph. Now make the calculations using log and antilog tables (given in the end of this book). If the result of you calculation is upto your satisfaction and close to the expected result, record the entire experiment in you practical note book carefully and systematically. If the result of your experimental calculations are not upto your satisfaction, consult with your teacher for the judgement of the correctness and for finding the fault, if any. In case the result of your calculation is incorrect check the calculations thoroughly and if necessary repeat the experiment.

While working with the apparatus, if you face any difficulty and confusions consult with your concerning teacher immediately without any hesitation and highlight the difficulty with full humble request.

If the experiment is to be performed jointly with other partner, come to the laboratory with full preparation on there own accord. Make effective share in performing experiment and take all the observations independently and make the calculations yourself, otherwise you will not be able to perform the experiment in the practical examination and you will be the main sufferer.

How to Record the Experiment

Students are advised to record the experiment on your practical note book according to the following scheme :

Day and date ....

Experiment No. ....

Object	:	*Here the object of the given experiment will be written.*
Apparatus required	:	*The list of the instruments required for performing the actual experiment will be given here.*
Diagram	:	*The circuit diagram in case of the experiment of electricity and electronics, and ray diagram in case of experiments on light is given on the left plane paper of the note book.*
Formula Used	:	*Here the formula, which is to be used for the calculation will be written along with the explanation of the symbol given in it.*
Observations	:	*Here the least count of the instrument used for the measurement along with the table for recording the experimental observations must be given.*
Graph	:	*The graph between the two interdependent variables must be drawn if required, on a graph paper and paste it on left page.*
Calculations	:	*Calculations must be done by using log and antilog tables and if necessary by using natural sin, cos and natural tangent tables.*
Result	:	*Here result must be mentioned with proper unit.*
Standard Result	:	*Here standard result must be written (if any)*
Percentage Error	:	*Here percentage error must be given.*
Precautions and sources of errors	:	*Here precautions taken during the performance of experiment and sources of errors are given.*

The above arrangement is extremely useful in maintaining a proper record. It should be remember that the experiment affords the opportunity to learn the habit of systematic observations, to do the things honestly, efficiently and regularly. Intelligent and sincere work is more important than accurate results.

❑

EXPERIMENT NO. : - 1 : NEWTON'S RING

NEWTON'S RING

OBJECT :- To determine the wavelength of sodium light by means of Newton's Ring.

APPARATUS:-

- A Plano convex lens of large radius of curvature,
- Optical arrangement for Newton's Ring,
- A plane glass plate,
- A traveling microscope and
- A monochromatic source (sodium lamp) provided with cover having a broad slit cut into it.

FORMULA USED: - The wave length of monochromatic source is given by

$$\boldsymbol{\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}}$$

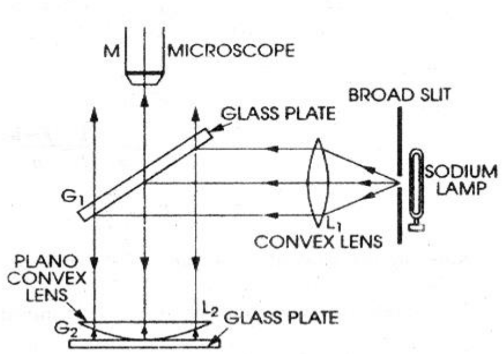
$\boldsymbol{D_{(n+p)}}$ = Diameter of the $(n + p)^{th}$ ring.

$\boldsymbol{D_n}$ = Diameter of the $(n)^{th}$ ring.

$\boldsymbol{p}$ = An integral number which is the difference in the order $(n + p)^{th} and\ (n)^{th}$ of two rings considers.

$\boldsymbol{R}$ = Radius of curvature of the curved surface of the Plano convex lens.

EXPERIMENTAL SETUP:



METHOD:

1. The surface of both of glass plate and the Plano - convex lens should first clean smoothly with handkerchief.
2. In order to focus the microscope, the eyepiece is first focused on the cross wires till they are clearly seen in the field of view. One of the cross-wire is made horizontal. The microscope is then focused on a cross mark (+) made on a piece of paper placed above the blackened glass plate. The lens has not been put as yet.
3. The paper is removed and the Plano - convex lens is put in its place with in curved surface in contact with the plate. The microscope is slightly adjusted so that the rings are clearly seen in the field of view. If the rings obtained are not circular then either the glass plate or lens or both are irregular. To obtain perfectly circular rings, one is shifted to other positions on the glass plate. Even the smaller portion of the plate around the point of contact. Sometimes the lens and the plate is not perfect on account of the presence of dust particles but this will not affect the experiment.
4. By moving the blackened glass plate (along with the lens) or the microscope this way or that way the horizontal cross-wire is made to pass through the center of the ring system

parallel to the scale so that the motion of this cross-wire may be along the diameter of the ring system.

5. The least count of the microscope is evaluated and recorded.
6. The microscope moved towards one side (say to the left of the central spot of certain numbers of dark and bright rings, say 21th ring) and then allowed to move towards the right. As soon as the other wire which is perpendicular to the direction of motion of the microscope of the cross-wires becomes just tangential of the outer edge of 20th dark or bright ring. The reading of microscope screw is noted. The motion of microscope towards the right is continued slowly by the circular screw and the readings of the screw are recorded every time the cross-wire becomes tangential to the outer edge of the every alternate dark or bright rings (e.g. 20th ,18th ,16th, etc.)

   On reaching the central spot position the cross-wires are moved further to the other side of it and the readings of the screw recorded every time the cross-wire becomes tangential to the inner edge of the alternate dark or bright rings and 4th,5th, etc till 20th dark or bright ring. Difference between the microscope readings on the outer edge on one side and inner edge another side of a ring will give its mean diameter.

   By properly recording and coupling these observations the mean value of $\boldsymbol{D_{n+p}^2 - D_n^2}$ is calculated. This can also be evaluated by drawing straight-line graph between D_n and n order of the ring. The radius of curvature of the curved surface of the Plano convex lens is noted.

OBSERVATIONS: -

Value of one division on Main Scale = --------------- mm

Total no. of division on Circular Scale = --------------

Least count of Microscope = $\frac{\text{Value of one division on Main Scale}}{\text{Total no. of division on Circular Scale}}$ = --------------- mm

No. of rings	**Microscope- reading when the cross wires is tangential to the**		**Diameter of the ring** $\boldsymbol{D^n}$ $\boldsymbol{mm.}$	$\boldsymbol{D_n^2}$ $\boldsymbol{mm^2}$	$\boldsymbol{D_{n+p}^2 - D_n^2}$	$\boldsymbol{p}$
	Outer edge (L.H.S.) $\downarrow$ $\boldsymbol{mm.}$ $(\boldsymbol{a})$	**Inner edge (R.H.S.)** $\uparrow$ $\boldsymbol{mm.}$ $(\boldsymbol{b})$	$\boldsymbol{D^n}$ $= (\boldsymbol{a} - \boldsymbol{b})$			
20						
18						
16						
14						
12						
10						
8						
6						**10**
4						
2						

Mean value of $\boldsymbol{D_{n+p}^2 - D_n^2}$ = ------------------------$\boldsymbol{mm^2}$ =-----------------$\boldsymbol{cm^2}$

Radius of curvature of the curved surface of the Plano convex lens R = 120 cm.

CALCULATIONS:

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}$$

RESULT:- The wave length of sodium light (by formula) = ------------10^{-8} cm. = ----------Å.
The wave length of sodium light (by graph) = ----------------10^{-8} cm. = -----------Å.
The wave length of sodium light (Average value) = ----------------10^{-8} cm. = --------------Å

Standard Wave length of Sodium light= 5893 Å.
Percentage error = ----------------- %

PRECAUTIONS: -

1. The lens and the glass plate should be dust free, otherwise central dark spot will not be obtained.
2. The inclination of the 45^o plate should be adjusted (if adjustable) till the rings are most distinct.
3. Black-lash error of the screw should be avoided by moving the microscope in one direction only.
4. For proper coupling of the observations,(to get the mean value of ($\mathbf{D^2}_{\mathbf{n+p}} - \mathbf{D^2}_{\mathbf{n}}$) an even number of observations should be taken.

VIVA –VOCE QUESTIONS

1. What are Newton's rings?
2. How are Newton's rings formed?
3. Why are the Newton's rings circular?
4. Why the Plano- convex lens of large focal length is used?
5. What is the function of 45^0 inclined plane glass plate?
6. Why do the rings get closer as the order of the rings increases?
7. Why is it necessary for the light to fall normally on the Plano – convex lens?
8. Why is the center of the rings dark?
9. What will happen if the plane glass plate is replaced by a plane mirror?
10. If sodium light is replaced by white light, what change is observed in the Newton's ring?
11. What will happen if few drops of a transparent liquid are introduced between the Plano – convex lens and the glass plate?
12. What will happen if the Plano – convex lens is replaced by a transparent glass plate inclined at a small angle with the lower glass plate?
13. What is the construction of a sodium lamp?
14. Why the sodium lamp first glows pink and then yellow?

EXPERIMENT NO. : - 2 VISCOSITY OF LIQUID

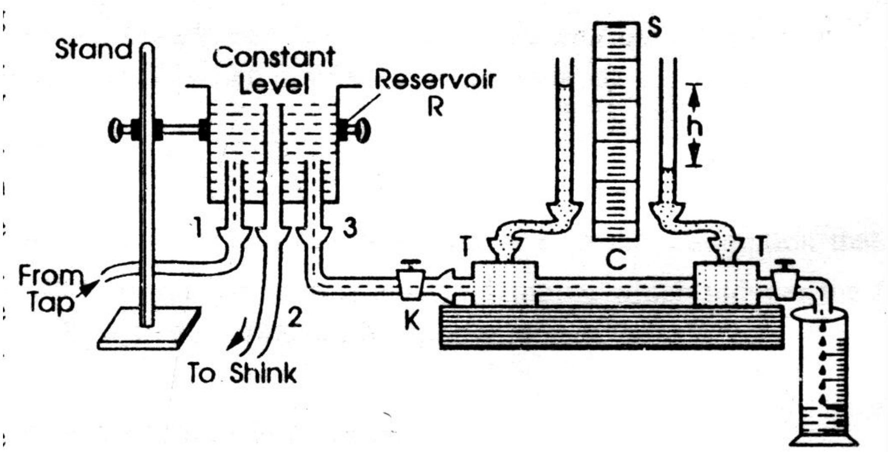
<u>**VISCOSITY OF LIQUID**</u>

OBJECT: To determine the coefficient of viscosity of water, by Poiseuille's method.
APPARATUS: A Capillary tube of uniform bore and a constant level reservoir fitted on a board, a manometer, stop watch and graduated jar.
FORMULA USED: The coefficient of Viscosity of a liquid is given by the formula

$$\boldsymbol{\eta = \frac{\pi P r^4}{8Vl} = \frac{\pi \rho g h r^4}{8Vl} Poise}$$

Where r= radius of capillary tube
V= volume of water collected per second
l= length of the capillary tube
ρ= density of liquid
h = difference of levels in manometer

EXPERIMENTAL SETUP:



PROCEDURE:

1. Allow the water to enter the constant level reservoir through tube (1) and leave through tube (2) in such a way that water comes drop by drop from the capillary tube. This is adjusted with the help of pinch cock K. It should be remembered that all the bubbles should be removed from the capillary.
2. When everything is steady collect the 20ml water in a graduated jar and note down the time taken and thus calculate the volume V of the water flowing per second.
3. Note the difference of the level of water in manometer. This gives h.
4. Vary h by raising or lowering the reservoir. For each value of h, find the value of V.
5. Measure the length and diameter of the tube.

OBSERVATIONS: Room Temperature= --------- ^{o}C

Sl.	Manometer Reading		Pressure Difference h (Cm)	Measurement of V		V= Cm^3 / Sec.	$\frac{h}{V}$
	One end (Cm)	Other end (Cm)		Total volume of water Collected Cm^3	Time t Sec.		

Mean value of (h/V)=

Temperature of water = ------------^{0}c
Length of capillary tube = ------------cm.
Diameter of capillary tube (2r) = 0.105 cm For Apparatus (i)
= 0.100 cm For Apparatus (ii)
Value of g at Bareilly = 979.17 cm/s^2
Density of Water = 1 x 10 ^{3} Kg/ m^3

CALCULATIONS:

The coefficient of viscosity η for water is given by;

$$\eta = \frac{\pi \rho g h r^4}{8Vl} Poise$$

RESULT: The coefficient of viscosity of water at ------------^{0}c = -----------------Poise

Standard value of coefficient of viscosity of water = 8 x 10 $^{-3}$ Poise

Percentage Error = ----------------- %

PRECAUTIONS AND SOURCES OF ERROR:

1. The tube should be placed horizontally to avoid the effect of gravity.
2. The value of h should not be made large and should be so adjusted that the water comes out as a streamline flow.
3. The radius should be measured very accurately as it occurs in fourth power in the formula.
4. The Pressure difference should be kept small to obtain streamline motion.

VIVA –VOCE QUISTIONS

1. What is the external agency in your experiment which maintains the flow?
2. Is it necessary to keep pressure difference between the ends of the tube constant?
3. Can you not connect the capillary tube directly with a water tap?
4. What is the reason of your choice of a long tube?
5. Is this method suitable for all liquids?
6. Why is the capillary tube kept horizontal?
7. Why do you use a capillary tube of uniform radius?
8. What will happen if a capillary tube of large diameter is used?
9. What are steady state and turbulent flows?
10. What is critical velocity?
11. On what factors does the critical velocity depend?
12. What is coefficient of viscosity?
13. What is the unit of the coefficient of viscosity?
14. How will you define poise?

EXPERIMENT NO. :- (3) NODAL – SLIDE

NODAL – SLIDE

OBJECT: - To determine the focal length of the combination of two thin convergent lenses separated by a distance with the help of a Nodal – Slide and verify to the formula.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

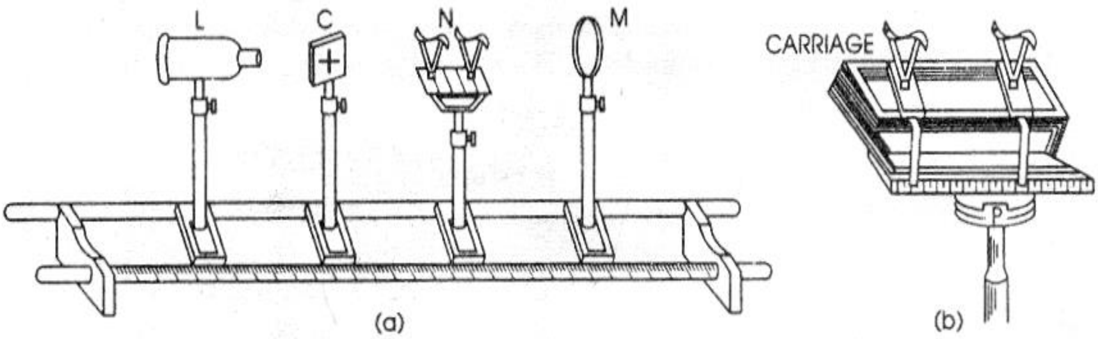
Where, F = focal length of the combination

f_1 *and* f_2 = focal length of the two lenses

x = Distance between the two lenses.

APPARATUS: - Nodal – Slide assembly (consisting of an optical bench, plane mirror, cross slit and lamp) and the two given lenses.

EXPERIMENTAL SETUP:



PRINCIPLE: The focal length of a lens system is the distance between its principal point and the corresponding focal point. The principal points coincide with the corresponding nodal points when the media are the same on both the sides of the system (here, air). Thus the focal length of the system can be determined by locating a nodal point and the corresponding focal point.

The second nodal point can be located by using the fact that in case of parallel beam of light incident on a convergent lens system, thus forming an image on a screen in its second focal plane, the image does not shift laterally when the system is rotated about a vertical axis passing through its second nodal point.

The distance between the uprights carrying the screen (or –cross- slit) and the nodal slide (which gives the position of the axis of rotation) will, therefore, give the focal length of the lens system.

METHOD: -

(1) First the focal length f_1 and f_2 of the two given lenses are determined. . For this one of the lenses is mounted on the nodal – slide such that its optical center lies on the axis of rotation of nodal slide. The source of light, screen having the cross slit and plane- mirror are mounted on the proper uprights and the heights of uprights are adjusted in such a manner that the line joining the center of each part is parallel to the bed of the bench.

(2) The cross- slit is illuminated and the plane of the mirror is adjusted till the image of the cross slit is formed close to the cross slit itself. If the image is blurred and not well defined then the upright carrying the nodal slides moved towards or away from the slit till the image

becomes sharp and well defined. (In this position light diverging from the cross-slit emerges as a parallel beam of light after passing through the lens. This parallel beam of light is reflected as a parallel beam from the plane–mirror and brought to focus on the plane of the cross- slit by the lens. In other words, the screen having the cross -slit serves as the second focal plane for the parallel beam of light coming from the plane mirror.)

(3) The slide is rotated slightly about the vertical axis and lateral shift of the image is observed. If there is any shift, the position of the axis of rotation with respect to the lens is slightly changed by moving the nodal slide on the upright by means of the screw provided for this purpose. The sharpness of the image is disturbed. The image is refocused by moving the upright (carrying the nodal slide) on the optical bench. Lateral shift of the image is again observed. The same process is repeated till the image of the slit is in sharp focus and does not show any lateral shift when the nodal slide is slightly rotated about its vertical axis. The distance between the plane of the cross slit and the axis of rotation now gives the focal length of the lens.

(4) The lens is rotated through 180^0 and the whole process is repeated. The mean of the two distances, thus obtained, will give the exact focal length “f” of the lens.

(5) The first lens is removed and the second lens is mounted on the nodal- side. Its focal length “f” is determined in the same manner as described.

(6) To determine the focal length of the combination, the two lenses are mounted on the nodal slide at some distance apart (the lenses are being placed equidistance and on opposite sides of the axis of rotation). By adjusting the inclination of the plane mirror and the position of the nodal slide the image of the cross slit is made to lie on the side of the slit itself. The shift in the image due to a slight rotation of the nodal slide is observed. If there is any lateral shift, with the simultaneous focusing of image a suitable position of the nodal slide is determined for which no lateral shift of the image occurs due to a slight rotation of the nodal slide. The distance between the plane of the screen and the axis of the rotation of the nodal slide now gives the focal length of the combination.

(7) Different sets of reading are to be taken by turning the faces of the lens through $180^0$and inter–changing the position of the component lenses.

(8) The experiment is repeated for different values of x- the distance between the lenses (say 4,6,8 cms)

(9) The focal length of the combination is also obtained theoretically for each value of x by the formula

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

$$F = \frac{f_1 f_2}{f_1 + f_2 - x}$$

It will be found that the experimental and theoretically values of the focal length of the combination for given separation agree fairy well thus verifying the truth of the formula.

OBSERVATIONS: -

(A) Observation for the focal length of the first lens:

S. No.	Light Incident On	Position Of The Cross-Slit (a) in cm.	Position Of The Axis Of Rotation Of The Nodal-Slide (b) in cm.	Focal Length $f_1 = (a - b)$ in cm.
1.	**One face**			
	Other face			
2.	**One face**			

	Other face			
3.	**One face**			
	Other face			

Mean f_1 = Cm.

(B) Observations for the focal length of the second lens:

S. No.	**Light Incident On**	**Position Of The Cross-Slit (a) in cm.**	**Position Of The Axis Of Rotation Of The Nodal-Slide (b) in cm.**	**Focal Length $f_2 = (a - b)$ in cm**
1.	**One face**			
	Other face			
2.	**One face**			
	Other face			
3.	**One face**			
	Other face			

Mean f_2 = Cm.

(C) Observations for the focal length of the combination:

S. No.	**Distance Between lenses (x) in cm.**	**Light Incident On**	**Position Of Cross Slit (a) cm.**	**Position Of The Axis Of Rotation Of The Nodal Slide (b) cm.**	**Focal Length Of The System (Exp.) F**	
					$(a \sim b)$ cm.	**Mean cm.**
1.	**4**	**One lens**				
		Other lens				
2.	**6**	**One lens**				
		Other lens				
3.	**8**	**One lens**				
		Other lens				

CALCULATION :

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

$$F = \frac{f_1 f_2}{f_1 + f_2 - x}$$

(a) For x = 4cm., Calculated F = ------------cm.
(b) For x = 6 cm. Calculated F = ------------cm.
(c) For x = 8 cm. Calculated F = ------------cm.

RESULTS:

SL.	Distance between the lenses (x) in cm	Focal Length of the system obtained (F)		Difference
		Experimentally (cm.) (a)	Theoretically (cm.) (b)	$(a \sim b)$
1	4			
2	6			
3	8			

From the above table it is obvious that the experimental and theoretical values of the focal length of the system are nearly the same for each value of x separately. Hence the formula $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$ is verified

PRECAUTIONS:

1. False images formed by partial reflection from the faces of the lenses should not be confused with the true image of the cross-slit.
2. While determining the focal length of a single lens, its optical centre must lie on the axis of rotation of the nodal slide. (for easy and quick setting)
3. Bench-error should also be taken into account.
4. The nodal slide should be rotated slightly about the axis of rotation.
5. In order to get a bright image of the slit the plane mirror should be placed as close to the combination as possible.

VIVA –VOCE QUESTIONS

1. What is nodal slide?
2. Why do you call it nodal slide?
3. What are nodal points, focal points and principal points?
4. What is the common name of all these three pairs of points of the coaxial optical system?
5. What is angular magnification?
6. What is lateral magnification?
8. What are principal planes?
9. What are focal planes?
10. What are nodal planes?
11. What is the importance of the cardinal points of the coaxial optical system?
12. Under what condition. the six cardinal points of an optical system reduce to four?

EXPERIMENT NO.:-4 B-H Curve

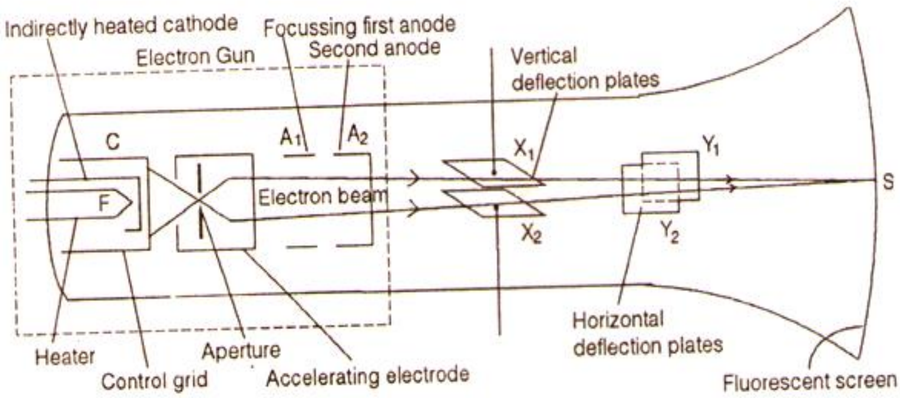
B-H Curve

OBJECT: - To draw hysteresis curve (B – H CURVE) of a given sample of a ferromagnetic material in the form of thin iron wires (or cycle spokes) on a cathode ray oscilloscope (C.R.O.) using a solenoid and to determine Retentivity, Coercivity and hysteresis loss from it.

APPARATUS: - C.R.O., Cycle spokes of iron, solenoid coil, step down transformer, rheostat (10 Ω), two condensers (of capacity 1μF and 2μF), A.C. ammeter, two one ohm resistors, one 47 KΩ carbon resistor, two carbon potentiometers of 20KΩ and 5KΩ resistance etc.

Description of Apparatus and Circuit: A solenoid is wound on a hollow tube of non-magnetic material (usually glass) of approximate diameter 1-2 cm and length of about 30 cm with a three layers winding of enameled copper wire (Standard wire Gauge SWG 22 or 24) on it.

A short secondary coil of nearly 10000 turns of SWG 46 or 48 enameled copper wire is wound centrally over a spool of nearly 10 cm length and about 5.0 cm diameter. A step down transformer 6-12 volt with 2-3 amperes capacity is used to supply an alternating current to the primary through a resistance R_1 (1Ω). Cycle spokes of iron or rods of 40-50 thin iron wires are inserted completely in the primary of the solenoid. The value of R_1 and applied e.m.f. will depend upon the degree of amplification which the C.R.O. provides. In the primary circuit the potential drop over a resistance is suitably added (with the help of 20 KΩ potentiometer) with the potential difference to be applied to Y-Y plates of C.R.O. It is essential to neutralise the contribution arising due to the coupling through air between secondary and primary. The current applied to the primary coil is proportional to the magnetizing field H. The voltage drop (e.m.f.) across the secondary is a measure of dB/dt. Hence, to get a magnetic flux density B an integrated circuit which is a combination of resistance R (47kΩ) and capacitance C (2μF) is connected with secondary coil. The resistance R should be much larger than reactance of the circuit (R>>Xc) but in practice, it cannot be made very large. As a result of this, there will be a phase difference between voltage drop V and B. Hence, for this phase correction a variable resistance (5KΩ) with a condenser (1μF) is connected in the circuit. The voltage proportional to the magnetic induction B is applied to the pair of Y plates of C.R.O. The deflection on the screen is calibrated in terms of H and B.



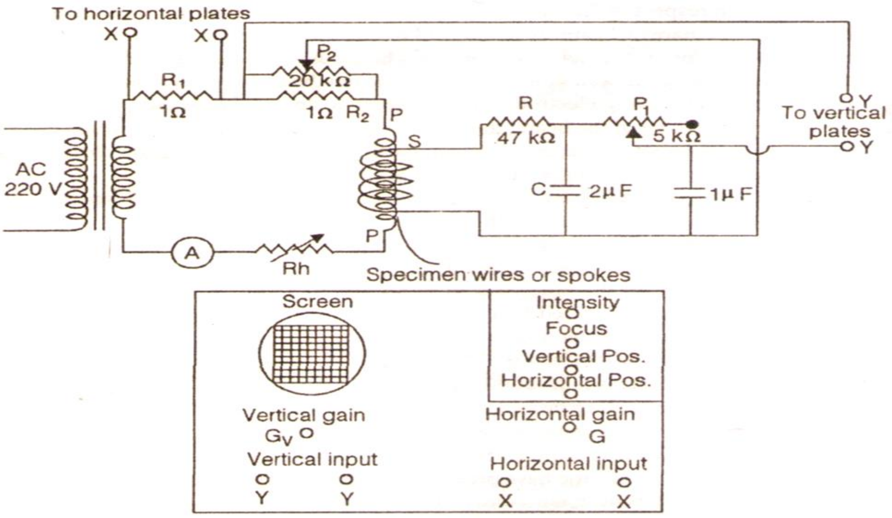


Fig. 15.4

Theory and Formula Used: When an A.C. current passes through the primary of the solenoid in which specimen rods are kept, then the magnetizing field produced by solenoid's primary is given by

$$H = \frac{4\,\pi\,ni}{10}\cos\omega t = \frac{4\,\pi\,n\,(\sqrt{2}\,I_{rms})}{10}\cos\omega t$$

Where n is the number of turns per length in the primary, I_{rms} is the root mean square value of current directly measured in A.C. ammeter. Its maximum value is

$$H_{max} = \frac{4\,\pi\,n\,(\sqrt{2}\,I_{rms})}{10} \qquad [\because\ (\cos\omega t)_{max} = 1]$$

The voltage developed across 1 ohm resistor R_1 is proportional to H and applies to X-X plate of C.R.O.

The induced voltage (e.m.f.) across the secondary coil is a measure of dB/dt. Hence to get magnetic flux density B through it an integrating circuit (R – C) is used. In the circuit arrangement 47 KΩ resistor and 2μF capacitor constitute this integrated circuit. The induced e.m.f. produced across the secondary is

$$e = -\frac{d}{dt}(\emptyset_B) = -\frac{d}{dt}(BAN) \qquad \text{or} \qquad e = -AN\frac{dB}{dt}$$

Its magnititude is $e = AN\frac{dB}{dt}$ ------------ (1)

Where A is the area of cross section of the solenoid, N the number of turns in the secondary. The instantaneous current i flowing in the circuit is

$$i = \frac{e}{R + (\frac{1}{\omega C})} \approx \frac{e}{R} \qquad (\because R \gg X_C \text{at } 50\ H_Z)$$

The voltage drop across the capacitor C or applied to the pair of Y-Y plate of C.R.O. is

$$V = \frac{q}{C} = \frac{1}{C}\int i\,dt = \frac{1}{C}\int\frac{e}{R}\,dt$$

From equation (1), we have

$$\text{Or}\quad V = \frac{1}{CR}\int AN\frac{dB}{dt}\,dt \qquad \text{or} \qquad V \propto \frac{B}{RC}$$

The voltage proportional to B when applied to Y-Y plates a hysteresis loop is obtained on C.R.O.

Procedure

Calibration of X –and Y- axes in terms of H and B

(A) Display of B.H. Curve on the Screen

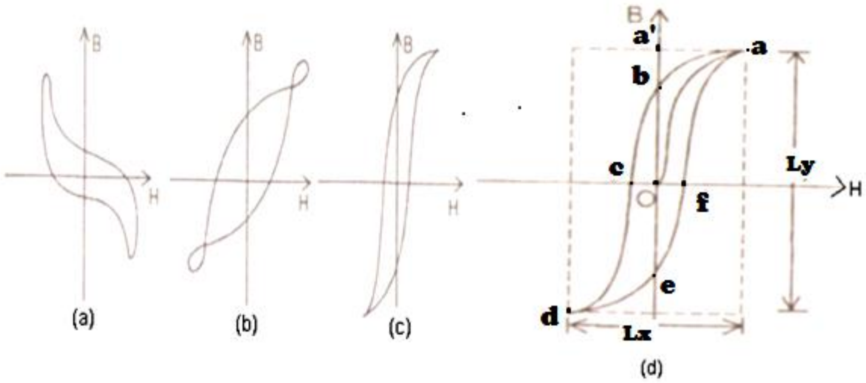
(1) After making necessary connections in accordance to the circuit diagram shown in fig. A.C. supply is switched on and rheostat Rh is adjusted to get maximum current in the primary of the solenoid.

(2) Adjust the vertical and horizontal gains of the C.R.O. with the help of gain control switches, G_h and G_v, to get the proper shape and size of the wave form on the screen. Usually the wave form obtained on screen is not of the desired shape. To get the correct shape following adjustments are made:

(i) If the shape of the curve obtained on the screen is as shown in fig. (a), then interchange secondary leads (Y-Y) to C.R.O. to bring the wave form in the proper quadrants.

(ii) If the shape of the curve is in accordance to the fig (b), then the potentiometer P_1 (5KΩ) is adjusted such that the curve becomes free from loops or flatness at the tips of the pattern.

(iii) If the curve obtained on the screen is similar to the fig (c), but ends of the curve are not parallel to H axis, then adjust the potentiometer P_2 (20KΩ) to make the ends horizontal. Moreover, if an increase in the resistance of P_2 increases the slope at the ends instead of reducing, then interchange the connections to Y- plates. For these adjustments X and Y amplifiers of the C.R.O. may be varied freely to get correct shape fig. (d)



(B) Tracing of B-H Curve:

(1) When the shape of the B-H Curve on C.R.O. screen becomes proper and correct fig (d), a tracing paper is put on the screen. Now, vertical gain is reduced to zero with the help of gain control switch, G_v by keeping horizontal gain maximum so that a straight line which indicates the H- axis obtained on the tracing paper.

(2) Similarly, horizontal gain is reduced to zero with the help of horizontal gain control switch G_h by keeping vertical gain maximum so that a straight line which indicates B-axis is obtained on the tracing paper. Now adjust the horizontal and vertical gain control switches to their previous positions to get a B-H curve of paper shape. Now trace this B-H curve on the paper for the calculation of various parameters.

(C) Calibration of X axis in terms of H

Measure the maximum deflection of spot along X – axis on tracing paper, let it be L_x. Hence, the calibration constant C_H for H – axis is

$$C_H = \frac{2\,H_{max}}{L_x} \text{ Oersted / cm}$$

(D) **Calibration of Y axis in terms of B**

(1) To calibrate Y- axis in terms of B, reduce horizontal gain to zero with the help of gain control switch G_h and also adjust potentiometer (20 KΩ) P_2 to the zero position so that no resistance acts in the secondary coil circuit. By doing so a vertical line equal to the height of the curve left. Measure this as L_y.

(2) Now take the specimen (cycle spokes or iron wire rods) slowly out of the primary of the solenoid till the length of vertical line reduces to its half value, that is, reduces to $L_y/2$.

(3) Now keeping the position of the specimen rod unchanged increase the vertical gain with the help of G_v to restore back the original length of the vertical line, that is, L_y. This implies that vertical gain is now become double to its previous value.

(4) Now the experimental rods or specimen is further taken out of the primary till the length of the vertical line further reduces to $L_y/2$. Now, again keeping the position of specimen rod unchanged further increase the vertical gain (G_v) to restore back the original length Ly of the vertical line again. At this time the vertical gain becomes four times to its initial value.

(5) Repeat the process once or twice more so that vertical gain G_v becomes 8- times or 16-times to its initial value provided specimen is not totally out of the solenoid's primary. Let this amplification factor be F = 2, 4, 8, 16 ……… depending upon the steps taken to increase it.

(6) Now the specimen is taken out of the solenoid completely and measure the length of the vertical line on the screen. Let it be h. The length of the vertical line h in the absence of specimen in the solenoid with original amplification will be h/F.

The vertical deflection h/F corresponds to double the maximum magnetic flux due to air core $(\phi_{air})_{max}$ or in the absence of any specimen in the solenoid's primary is given as.

$$2(\emptyset_{air})_{max} = 2\, H_{max} \pi r^2$$

Where r is the mean radius of the primary coil. Therefore, the calibration constant for flux measurement is $C = \frac{2\, H_{max} \pi r^2}{\left(\frac{h}{F}\right)}$ maxwell/cm

It B is the magnetic induction in the iron wires (or spokes or specimen) and S their area of cross section, then $\Phi_{max} = B.S$

Hence, the calibration constant for B is $C_B = \frac{C}{S} = \frac{2\, H_{max} \pi r^2}{\left(\frac{h}{F}\right) S}$ Gauss/cm

Where $H_{max} = \frac{4\, \pi\, n\, I_{rms} \sqrt{2}}{10}$ Oersted

OBSERVATIONS:-

(A) Constants for calibration of X – axis in terms of H

Current in the primary of the solenoid with specimen (ammeter reading), Irms = ------ amp

No of turns per unit length of the Primary, n = N/l = 800 turns/cms

(B) Constants for calibration of Y-axis in terms of B

Mean radius of the primary of the solenoid, r = 1.8 cm

Mean radius of one specimen wire or spoke R = 0.0535 cm

Total number of iron wire (or spokes) used N_1= ------------

Total area of cross section of all specimen wires or spokes, $S = (\pi R^2)N_1$ = ------- cm^2

The vertical gain or amplification factor, F = ------------

Length of the vertical line on the screen with air as core (without specimen), h = -------cm

(C) From the trace of B – H curve

Horizontal length of the curve, L_x = ----------- cm

Vertical length of the curve, L_y = ----------- cm

CALCULATIONS:-

1- Calibration constants

Maximum value of magnetizing field $H_{max} = \frac{4\,\pi\,n\,I_{rms}\sqrt{2}}{10}$ = -------------- Oersted

Calibration constant for X-axis in terms of H $C_H = \frac{2H_{max}}{L_x}$ = ----------- Oersted/cm

Calibration constant for Y-axis in terms of B $C_B = \frac{2H_{max}\,\pi r^2 F}{hS}$ = --------- gauss/cm

2- Magnetic constant from B – H curve

From fig (d)

Ob = -------- cm

So Retentivity = Ob x C_B = ----------- gauss

Oa' = --------- cm

So B_{max} = Oa' x C_B = ---------- gauss

Oc = ----------- cm

So Coercivity = Oc x C_H = ------------- Oersted

3- Area of the B – H Curve

Area enclosed by B – H curve on the screen S' = ------------ cm^2

Hence, the hysteresis loss per cycle per unit volume = $\frac{1}{4\pi}$ (area of the B − H Curve)

$= \frac{1}{4\pi}(S' X\ C_H\ X\ C_B)$

= ------------ ergs per cycle per cm^3

RESULT:-

1- The hysteresis curve (B – H curve) for given ferromagnetic material (Say iron) is shown on the attached tracing paper.

2- Retentivity of ferromagnetic material such as iron = --------- gauss.
Coercivity of ferromagnetic material = ---------- Oersted

3- Energy loss per cycle per unit volume or Hysteresis loss per cycle per unit volume
= ----------- ergs/cycle/cm^3

Precautions and Sources of Errors

1- Intensity of light on the screen of C.R.O. should not be large to avoid the burning of screen.

2- The current flowing in the primary coil of the solenoid should be sufficiently large so that the magnetising field produced should be enough to magnetise the specimen fully.

3- The C.R.O. should be carefully handled.

VIVA –VOCE QUESTIONS

1. What is B-H curve?
2. What is retentivity?
3. What is coercivity?
4. What is magnetic susceptibility?
5. Define intensity of magnetization.
6. What is Hysteresis loss?
7. Define magnetic flux density?
8. What is magnetic moment?
9. What is the use of CRO?
10. How you can measure the area of B-H curve traced on a graph paper?

EXPERIMENT NO. :- 5 DIFFRACTION GRATING

DIFFRACTION GRATING

OBJECT: To determine the wavelength of prominent spectral lines of mercury light by a plane transmission grating, using normal incident method.

APPARATUS:

i. Mercury lamp.
ii. Spectrometer,
iii. Grating
iv. A reading lens.

FORMULA USED: The wavelength of any spectral line can be obtained from the formula.

$$(\boldsymbol{e} + \boldsymbol{d}) \quad \boldsymbol{Sin\,\theta} = \boldsymbol{n\lambda}$$

or,

$$\boldsymbol{\lambda} = \frac{(\boldsymbol{e} + \boldsymbol{d}) \quad \boldsymbol{Sin\,\theta}}{\boldsymbol{n}}$$

Where, $(e + d) = grating\ element$
$\theta = angle\ of\ diffraction$
$n = order\ of\ principal\ maxima$

METHOD: Adjustment / Setting

1. Spectrometer should be adjusted for parallel rays.
2. Prism table must be optically leveled.
3. Grating should be normal to the collimeter axis.
4. The least count of the spectrometer is determined.
5. The grating is mounted on the prism – table such that it passes through the centre of the table and is made approximately normal to the axis of the collimeter by rotating the prism table.
6. The direct image of the slit is then made to coincide with the vertical cross wire of the telescope. This reading of the telescope is recorded.
7. The telescope is then rotated through 90^0 from this position and clamped.
8. The prism table is now rotated till the image of the slit, formed by reflection from the grating is thrown on the cross-wire. The position the grating is inclined at an angle of 45^0 or 135^0 to the collimeter axis.
9. The prism table is then rotated through 45^0 from this position. The plane of the grating thus becomes normal to the collimeter axis.

(B) READINGS FOR THE ANGLE OF DIFFEREACTION ARE TAKEN AS FOLLWOS:

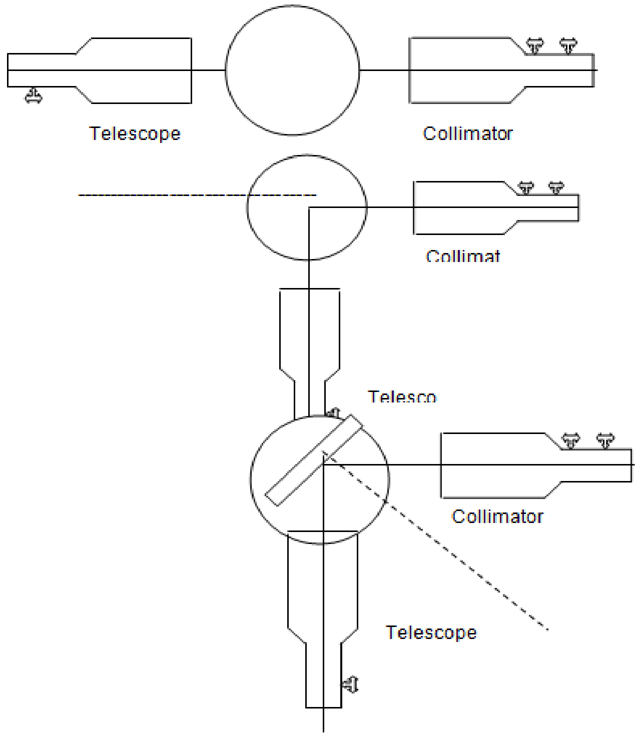
The telescope is unscrewed and rotated on one side (say left) of the direct image till it goes beyond the second order spectrum. It is then turned back and reading of both the scales and recorded whenever a spectral line mentioning the colours of the line coincides with the vertical cross wire. The spectral lines will be seen in the order of orange, yellow, green, blue and violet. This is done till the reading of both the verniers on both the sides of the direct image have been recorded (the telescope, being rotated in the same direction). The difference between the readings of the same vernier on the two sides for the same spectral line gives the value of the 2θ.

ADJUSTMENT OF GRATING FOR NORMAL INCIDENCE

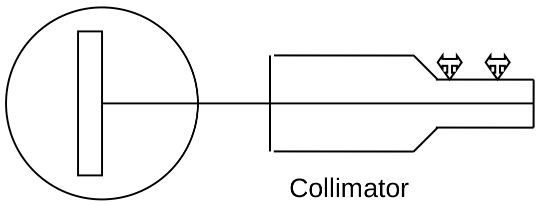
Step 1

Step 2

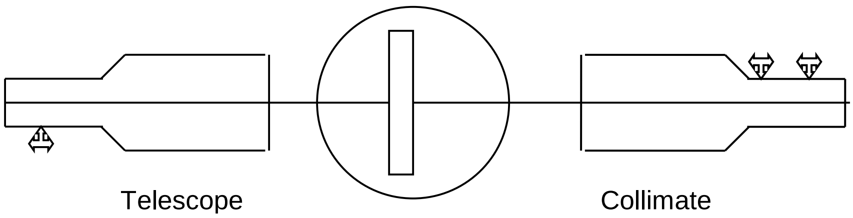
Step 3



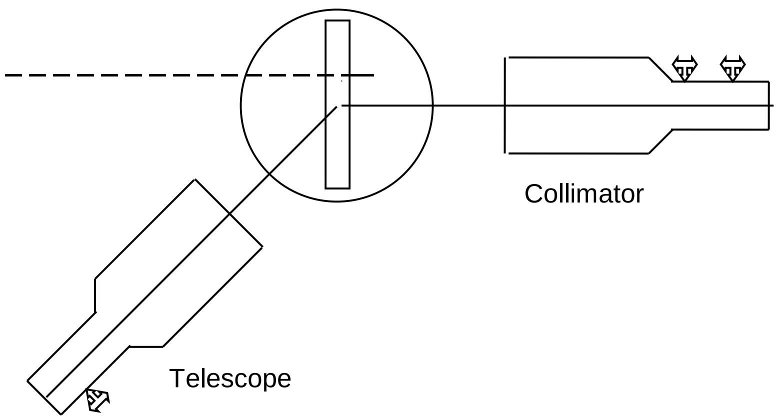
Step 4



Step 5



Step 6



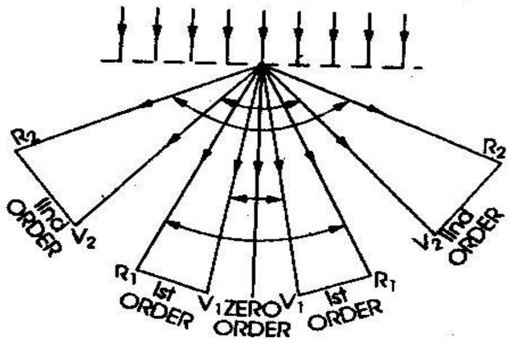
(C) The number of lines per inch (L.P.I.) which is written on the grating is noted and the grating element is evaluated from the relation.

$$(e+d) = \frac{2.54\ cm}{number\ of\ lines\ per\ inch}$$

(D) Knowing the various quantities, the wavelength of sodium light is calculated from the formula:

$$\lambda = \frac{(e+d)\sin\theta}{n}$$

EXPERIMENTAL SETUP:



EX.5

OBSERVATION:

(1) Observation for adjustment of the grating :
Least Count of the spectrometer = ………………… = Degree

(2) Observations for the grating element:
Number of lines per inch on the grating = …………..

Grating element $(e+d) = \frac{2.54\ cm}{number\ of\ lines\ per\ inch}$

$= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\, cm.$

(3) Observations for angle of diffraction :

Order of Spectrum	**Colour of Spectrum**	**Reading for the Spectrum on**				**Value of 2θ**			**Value of θ**
		L.H.S.		**R.H.S.**		**Vernier**			
		V_1 (a)	**V_2 (b)**	**V_1 (c)**	**V_2 (d)**	**1st a~c**	**2nd b~d**	**Mean**	
1st	**<u>Violet</u>**								
	Green								
	Yellow								

CALCULATIONS:

$$\lambda = \frac{(e+d)\ \sin\theta}{n}$$

$$For\ Violet\ color, first\ order\ (n=1)\lambda = --\ cm\ = ---\text{Å}$$
$$For\ green\ color\ (n=1)\quad \lambda = --\ cm. = --\text{Å}$$
$$For\ yellow\ color\ (n=1)\quad \lambda = --cm. = --\ \text{Å}$$

RESULT: The wavelength of various spectral lines of mercury are as follows:-

Colour of Spectral Lines	Observed Wavelength 10^{-8} cm. or A^0	Standard Wavelength	Percentage Error
Violet		**4058 Å**	
Green		**5461 Å**	
Yellow		**5791 Å**	

PRECAUTION

1. The grating should not be touched with hand or rubbed. It should always be held by means of fingers kept on the opposite edges of the grating.
2. Grating should be perfectly normal to the axis of the collimeter.
3. The prism – table must be leveled optically.
4. While recording observations the telescope should be rotated in the same direction in order to avoid backlash error.
5. The slit should be as narrow as possible.
6. All the preliminary adjustments of the spectrometer must be made before starting the experiment.
7. While taking observations the turn table must remain clamped.
8. Both scales should be read.

VIVA – VOCE QUESTIONS

1. What is a diffraction grating?
2. What is grating element?
3. What is dispersive power of grating?
4. When even orders spectral are absent in a grating spectrum?
5. What is difference between a prism and grating spectrum?
6. How many orders of spectra are seen here?
7. Why more than this orders are not possible?
8. Why is the red colour diffracted most in case of grating?
9. What are the essential parts of a spectrometer?
10. How will you adjust the collimator?
11. Why do you use two Verviers in this experiment?

EXPERIMENT NO. : - 6 CARRY FOSTER'S BRIDGE

CARRY FOSTER'S BRIDGE

OBJECT: To determine the resistance per unit length of Carry Foster's Bridges wire and the specific resistance of the given wire by comparing the resistance of wire with standard resistance.

APPARATUS: -

- Carry foster's bridge,
- Rheostat of range near about to 100 ohm.(or two resistance boxes)
- Lechlanche cell,
- Thick copper strip,
- Galvanometer,
- Plug key
- Wire whose specific resistance is to be determined, standard 0.1 ohm resistance and connecting wires.

FORMULA USED: The difference between two nearly equal resistance connected in the outer gaps of a carry fosters bridges is given by

$$R - \boldsymbol{\gamma} \;=\; K\,(l_1 - l_2) \quad \text{----------------------------- (1)}$$

Where K = resistance per unit length of the bridge wire.

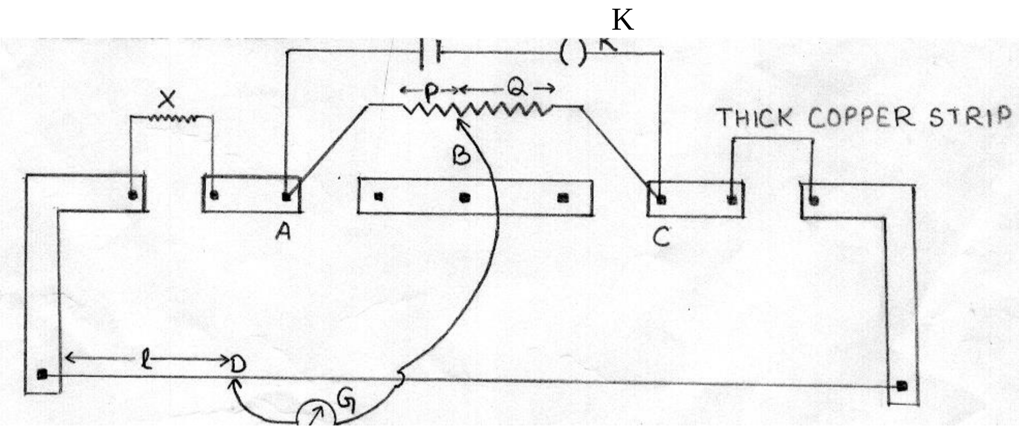
$(l_1 \; and \; l_2)$ = distance of the null point, from left of the bridge wire with the resistance $\boldsymbol{\gamma}$ in right and left outer gaps respectively.

This equation can be used in evaluate K, if R and $\boldsymbol{\gamma}$ are known and R if $\boldsymbol{\gamma}$ and K are known. Having obtained the resistance X of the given wire, the specific resistance ρ of material can be calculated from the formula

$$\boldsymbol{\rho} = \frac{\boldsymbol{X\pi r^2}}{\boldsymbol{l}}$$

Where l and r stand for the length and radius of the given wire.

EXPERIMENTAL SETUP:



METHOD: The method can be determined into three separate parts.

(A) Method For Determination of The Resistance Per Unit Length of The Bridge Wire.

1. The standard 1.0 or 0.5 ohm resistance is kept in the outer left gap for R and thick copper strip in the outer right gap for $\boldsymbol{\gamma}$. It is very essential that thick short copper wire be used to

connect the standard resistance in the gap. The ratio arms P and Q can be obtained by connecting the lower terminals of the rheostat to the point. A and C and its upper terminal connected to the sliding contact to the galvanometer G. In place of the rheostat two resistance boxes can also be used and connected between the terminals A, B and B, C respectively. Some ratio P: Q is applied by introducing some resistance in the boxes.

2. The cell key K is closed and the jockey is then made to touch the bridge wire near its ends. If the deflections in the galvanometer in the two cases are in opposite directions then the connections are correct. If however only one-sided deflection is observed then the connection are rechecked and screws properly tightened, seeing that the end of the connecting wire are perfectly clean. When deflection on both the sides occur then the position of the jockey is so found that there is no deflection in the galvanometer. The distance of the null point D from the left and of the wire is noted. Copper strip and standard resistance are interchanged and the distance of l_2 of the null point from the same end is noted.
3. The ratio P: Q is then changed to some other value by slightly displacing the sliding contact of the rheostat or by introducing some other resistance in the resistance boxes, used for this purpose. The experiment in then again repeated and the distance of the null point found out by keeping the copper strip in the right gap first and left gap after words.
4. Several sets of observations are taken in this manner by change. P: Q from set of set and then covering nearly the entire length of the bridge wire.
5. The value of $(l_1 - l_2))$ is determined for each set and the mean value of $(1/\ (l_1 - l_2))$ is evaluated. This when substituted in equation taken $\boldsymbol{\gamma}$ = 0 (thick copper strip and R standard resistance (1.0 or 0.5 ohms) used will give $K = \ (R/(l_2 - l_1))$.

(B) **METHOD FOR DETERMINING THE RESISTANCE OF THE GIVEN WIRE: -**

The experiment is performed exactly in the same manner as started above by replacing the standard 1.0 or 0.5 ohms resistance with the given wire and retaining the copper strip for $\boldsymbol{\gamma}$. The mean value of $(l'_2 - l'_2)$is then found out in this case. The resistance of the given wire is then calculated from the formula (1) which gives $X = \ K\ (l_2 - l_1)$ Or $X\ = \boldsymbol{\gamma}\ +\ K(l'_2 - l'_1)$. The value of $K(l'_2 - l'_2)$. will change sign if proper order is not followed.

(c) **DETERMINATION OF THE LENGTH AND DIAMETER OF THE GIVEN WIRE FOR EVALUATING ITS SPECIFIC – RESISTANCE:**

1. The length of the resistance wire between the terminals, is measured by a meter scale and its mean radius is obtained by measuring its diameter at each place in two mutually perpendiculars directions by a screw gauge.
2. Having obtained the values of the resistance is calculated from the formula (2) given above.

OBSERVATION:

(A) OBSERVATION FOR DETERMINATION OF K:

S. No.	Standard resistance (R) used	Distance of null point from the left end of bridge wire with the copper strip (γ = 0) in		$(l_2 - l_1))$ cm.	Resistance per unit length $K = \ (R/(l_2 - l_1))$
		Right gap (l_1) cm.	Left gap (l_2) cm.		
1.	**0.1**				
2.	0.2				
3.	0.3				
4.	0.4				
5.	0.5				

$$Mean\ K =$$

(B) OBSERVATION FOR DETERMINATION OF THE RESISTANCE OF THE GIVEN WIRE :

S. No.	Distance of null point from the left end of the bridge wire with the copper strip (γ =0) in		$((l'_2 - l'_1)$ cm
	Right gap (l_1') cm	Left gap (l_2') cm	
1.			

(C) OBSERVATION FOR LENGTH AND DIAMETER OF THE GIVEN WIRE :

Length of the given wire =________ cm.
Least count of the screw gauge =________ cm.
Zero error =________ cm.

Diameter of given wire = ……………………….cm.

CALCULATION: Calculation for K :

$$R - \boldsymbol{\gamma} = \boldsymbol{K}\,(l_2 - l_1))$$

$$\because \quad \boldsymbol{\gamma} = 0; \quad \therefore \quad \boldsymbol{K} = R/(l_2 - l_1))$$

$$\boldsymbol{K} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ ohm/cm$$

Calculation for X (resistance of the given wire);

$$X = \boldsymbol{\gamma} + K(l'_2 - l'_1).$$

$$X = \mathbf{0} + \boldsymbol{K}\,(l'_2 - l'_1).$$

$\boldsymbol{X} = \ldots\ldots\ldots\ldots\ ohm$ (γ is Zero, if copper strip has been used)

Resistance of the given wire $\boldsymbol{X} = \cdots\ldots\ldots\ldots\ ohm$

Calculation for specific resistance ρ**:**

$$\boldsymbol{\rho} = \frac{\boldsymbol{X\pi r^2}}{\boldsymbol{l}}$$

ρ = ……………..Ohm cm

RESULT:-

1. Resistance per unit length of the bridge wire
   $\boldsymbol{K} = \ldots\ldots\ ohm/cm$
2. Specific resistance of the material of the given wire ρ = ……………..Ohm cm
3. **Standard Specific resistance of the given wire (Constanan) = 49 x 10^{-6} Ohms cm**.
4. Percentage Error = %

PRECAUTION AND SOURCES OF ERROR: -

1. Only thick short copper wire be used to connect the standard resistance in the gap.
2. A plug key should be used with the cell and it should be closed only while observations are being made.
3. While checking the null point the cell key should be closed first and then the jockey should be made to touch the bridge wire.
4. The jockey should be pressed gently and momentarily. IT should not be dragged along the length of wire otherwise it will spoil the bridge wire.
5. While determining the value of **ρ** the value of the standard resistance should be smaller than the resistance of the bridge wire, otherwise null point shall not be obtained.

VIVA – VOCE QUESTIONS

1. What is specific resistance?
2. What is resistance?
3. What is the effect of temperature on resistance?
4. In what materials, the resistance decreases with increasing temperature.
5. If the radius of the wire is doubled, will the specific resistance change?
6. If not, explain it.
7. What is the principle of Carey Foster’s bridge?
8. What is the principle of Whetstone’s bridge?
9. When is the C.F. bridge most sensitive?
10. What is the maximum difference in the two resistances that can be measured with it?
11. What is the minimum difference in resistance that can be measured with it?

EXPERIMENT NO. : - 7 VARIATION OF MAGNETIC FIELD

VARIATION OF MAGNETIC FIELD

OBJECT: - To plot graph showing the variation of magnetic field with distance along the axis of a circular coil carrying current and evaluate from it the radius of the coil.

APPARATUS: -

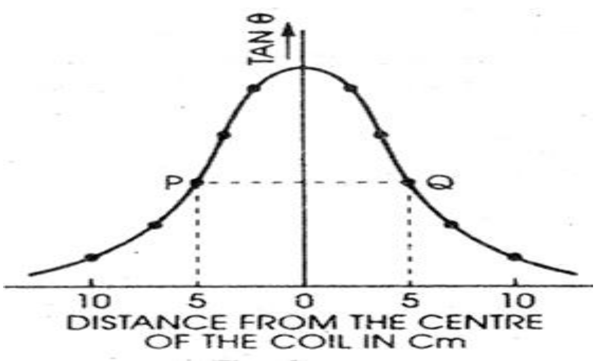
1. Stewart and Gee type galvanometer,
2. Storage battery,
3. Rheostat,
4. Commutator and
5. Connecting wires.

FORMULA USED: - The magnetic force of current carrying coli is given by

$$F = H\tan(\theta) = \frac{2\pi n i a^2}{(x^2+a^2)^{3/2}}$$

Where,
n = used number of turns of the coil
a = radius of the coil
i = current (in amp.) flowing through the coil
x = distance of the axial point from the centre of the coil
H = horizontal component of earth's field in the lab.
θ = deflection produced in the magnetic field of the galvanometer when the coil has been placed in the magnetic meridian.

On plotting the graph between x and Tan θ a curve m as shown in figure is obtained. The distance between the points of inflection P and Q is measured. This gives the radius "a" of the coil.

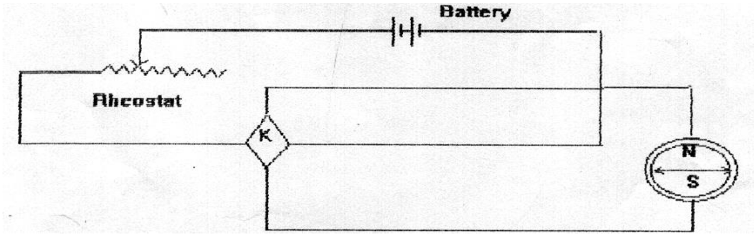


METHOD: -

1. The coil of the galvanometer is set into magnetic meridian. For this the arms are moved this way or that till the magnetic needle of the compass box lies nearly at the centre of the coil. The bench is then rotated in the horizontal plane till the coil is set roughly in the magnetic meridian. In this case, on looking vertically downwards from above coil; the coil, the magnetic needle and its image formed in mirror kept below it in the compass box, all lie in the same vertical plane. The compass box is rotated till the pointer read zero on the circular scale.
2. Connections are made as shown in figure using say 50 turns of the coil and taking care that out of the four terminals provided on the commutator K any two diagonally opposite

terminals are joined to the galvanometer and the other two to the battery through rheostat. The current is then passed by inserting the plugs in one of the pairs of opposite gaps of the commutator.

EXPERIMENTAL SETUP:



3. The value of the current is adjusted by means of the rheostat such that nearly 45^o deflection is produced in the needle. This is because the instruments is most sensitive at θ =45^o. The direction of the current in the galvanometer is then reversed by putting the plugs in the other pair of opposite gaps of the commutator and the deflection in the needle is again observed. If the difference between the deflections in the cases is less than 2^o the adjustment is correct (i.e. the coil lies in the magnetic meridian). Otherwise the coil is further rotated along with the bench till the two deflections agree within this range.
4. The current is then changed to such a value that the deflection in the needle is about 75^o (the number of turns used may be changed to 50, if this much deflection is not possible by using 5 turns). The readings of both the ends of the pointer (θ_1, θ_2) are noted. The direction of the current is reversed and again reading of both ends of pointers (θ_3, θ_4) is noted. The mean of the four reading will give the mean deflection.
5. The compass box is initially at the center of the coil and has maximum deflection 75^0. Now compass box is shifted in steps of 2 cm an east side and the corresponding readings are noted till the deflection falls to nearly 15^0.
6. Similarly the compass box is shifted in west side from center of coil, by sliding the wooden bench in steps of 2 cm and the corresponding reading is noted.
7. The graph between the position of the compass box and tan θ is plotted when a curve, as shown in figure is obtained.
8. The distance between the two points of inflection at A and B is found out from the graph. This should be equal to the radius of the coil.
9. The circumference of the coil can be measured by a thread and its radius can be calculated to verify the value obtained from the graph.

OBSERVATIONS: -

S. No	Position of the needle on one of the scale. (Distance of Compass box from center of coil)x (cm.)	Deflection in the needle when it is on the											
		East side of the coil						West side of the coil					
		Current one way		Current reversed		Mean θ^o	$tan\,\theta$	Current one way		Current reversed		Mean θ^o	$tan\,\theta$
		θ_1	θ_2	θ_3	θ_4			θ_1	θ_2	θ_3	θ_4		
1.	0												
2.	1												
3.	2												
4.	3												
5.	4												

6.	5												
7.	6												
8.	7												
9.	8												
10.	9												
11.	10												

Circumference of the coil as obtained by a thread and meter scale = 68.5 cm.

CALCULATION:-

Radius of the coil, as obtained from the graph = distance between the point P and Q
=.. cm.

Radius of the coil, as obtained from measurement = $\dfrac{Its\ Circumference}{2\pi}$

RESULT: - 1. The variation in the magnetic field with distance, along the axis of the given coil is as shown in the graph.

2. Radius of the coil = --------------- cm. as obtained from the graph
   Radius of the coil = ----------------cm. (From measurement).
3. Difference in Radius ----------

PRECAUTIONS: -

1. There should be no magnetic material or current carrying conductor in the neighborhood of the apparatus.
2. The coil should be adjusted in the magnetic meridian carefully and this should be tested by passing the current through it in one direction and then in the reverse direction. The deflection in two cases should be very nearly the same and must not differ by more than 2^o. Further, in this part of the experiment the current should be such that the deflection produced is nearly 45^o. This is because the instrument is most sensitive at $\theta = 45^o$.
3. After checking the setting of the coil in the magnetic meridian the current should be changed so that it may produce nearly 45^o deflection in the needle. By so doing the deflection near the inflection point is nearly 45^o and hence it can be located with greatest accuracy.
4. Initial reading of the pointer must be set zero. If there is any error it must be taken into account while recording the deflection**.**

VIVA –VOCE QUESTIONS

1. How does the field vary along the axis of the coil?
2. What is the magnitude of the field at the center?
3. How can you increase the region of uniform field?
4. Whether the field is uniform at the center or not?
5. What precautions should be taken in this experiment?
6. What is the strength of magnetic field at any point on the axis of circular coil?
7. What is the strength of magnetic field at the center of the coil?
8. What is tangent law?
9. Why is it necessary to set the plane of the coil in magnetic meridian?
10. What is magnetic meridian?
11. What is point of inflexion?
12. What is distance between the two points of inflexion?
13. Why is a mirror provided below the pointer in the compass box?

EXPERIMENT NO. : - 8 STEFAN’S LAW

OBJECT: To verify Stefan's Law by electrical method.

APPARATUS: 6V battery, D.C. Voltmeter (0-10 V), D.C. Ammeter (0-1 amp.), Electric bulb having tungsten filament of 6W, 6V, Rheostat (100 ohm).

THEORY AND FORMULA USED: -

For black bodies, Stefan's Law is

$$E = \sigma\,(T^4 - T_0^4)$$

Where E is the net amount of radiation emitted per second per unit area by a body at temperature T and surrounded by another body at temperature T_o. σ is called Stefan's constant. A similar relation can also hold for bodies that are not black. In such case we can write

$$P = C\,(T^\alpha - T_0^\alpha)$$

Where P is the total power emitted by a body at temp. T surrounded by another at temp. T_o α is a power quite closed to 4 and C is some constant depending on the material and area of such a body. Further the relation can be put as

$$P = C\,T^\alpha\,(1 - \frac{T_0^\alpha}{T^\alpha})$$

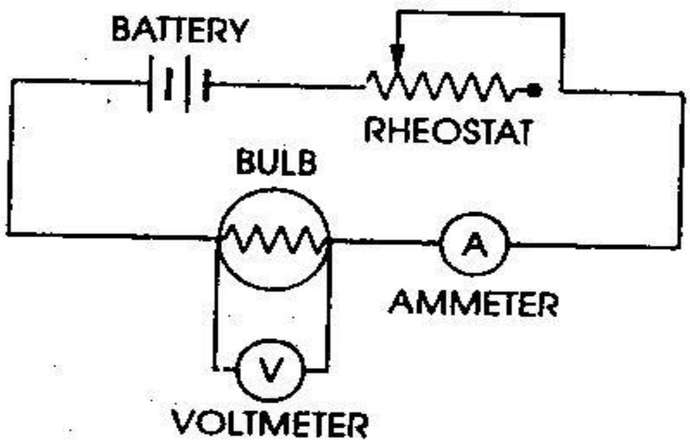
$$If\ \ T >> T_o\ (e.g. T = 1500k\ and\ T_o = 300k)$$

$$P = C\,T^\alpha$$

Taking log we get

$$\boxed{\log P = \alpha \log T + \log C}$$

EXPERIMENTAL SETUP



PROCEDURE:

1. Increase voltage V in such a way that voltmeter reads, 0.1, 0.3, 0.5, 0.7, 0.9, 1.0, 1.5, 2.0, 2.5, 3.0,3.5,4.0,4.5,5.0,5.5,6.0,6.5,7.0,7.5,8.0 Volts. And note the corresponding current I.
2. Calculate resistance $R_t = V/I$ and $P = VI$ for each set.
3. Draw a graph between log P (Y axis) Vs log T (X axis). Find the slope of this graph.
4. If the slope is of the order of 4 then Stefan's Law is verified.

OBSERVATIONS:-

Table. Determination of power dissipated, P for different temp. T.

Sl.	**Potential Difference V Volts**	**Current I amp.**	Resistance R = V /I Ohms.	**Power P = V I Watts.**	**Temp. T °K**	**Log P**	**Log T**
1.	**0.1**						
2.	**0.3**						
3.	**0.5**						
4.	**0.7**						
5.	**0.9**						
6.	**1.0**						
7.	**1.5**						
8.	**2.0**						
9.	**2.5**						
10.	**3.0**						
11.	**3.5**						
12.	**4.0**						
13.	**4.5**						
14.	**5.0**						
15.	**5.5**						
16.	**6.0**						
17.	**6.5**						
18.	**7.0**						
19.	**7.5**						

CALCULATIONS: - The temperature T corresponding to R_t are calculated using the following relation

$$\frac{R_t}{R_0} = \left(\frac{T}{T_0}\right)^x$$

Where x = 1.22, R_o = 0.6 ohm and T_o = 300 ^{o} K

RESULT: - The graph of log P Vs log T comes out to be a straight line having slope……..
Hence P = CT^α law is verified. Further the slope of the line α = 4 and therefore the law is verified as a fourth power law.

SOURCE OF ERROR: - A probable source of error lies in the determination of temperature. To minimize the error, care should be taken to measure the filament resistance as accurately as possible.

VIVA- VOCE QUESTIONS

1. What is Stefan's law?
2. How do you calculate temperature of the filament?
3. What is Stefan's law for the black body?
4. What is the value of Stefan's Constant?
5. What is emissive power? What is absorptive power?
7. What is Kirchhoff's law of radiation?
8. What is a black body?
9. Which is the radiating body in this experiment? What is the importance of Stefan's Constant

EXPERIMENT NO. :- 9 ENERGY BAND GAP

ENERGY BAND GAP

OBJECT: To determine the energy band gap in a semiconductor material taken in the form of a pn– junction diode.

APPARATUS:
1. Power supply (DC–3 volts)
2. Micro ammeter,
3. heating arrangement to heat the diode,
4. Thermometer,
5. Semiconductor diode.

FORMULA:
The reverse saturation current, Is is the function of temperature (T) of the junction diode. For a small range of temperatures, the relation is expressed as,

$$\log_{10} I_s = Constant - \frac{5.036\, X\, 10^3 E_g}{T}$$

Where, T is temperature in Kelvin (K) and E_g is the band gap in electron volts (eV).
Graph between $\frac{10^3}{T}$ as abscissa and $\log_{10} I_s$ as ordinate will be a straight line having

$$slope = 5.036\, E_g$$

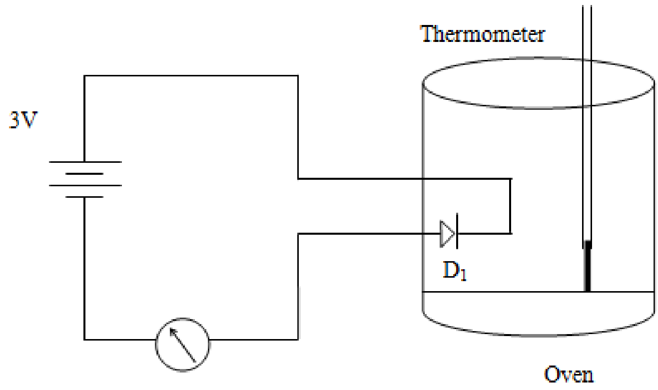
Hence band gap,

$$E_g = \frac{Slope\ of\ line}{5.036}\ eV$$

The energy band gap is given by

$$E_g = Slope\ of\ line \times 0.198\, eV$$

EXPERIMENTAL SETUP:



PROCEDURE :
1. The diode and the thermometer are kept in their respective receptacle in the oven.
2. The apparatus is switched on. The room temperature and the current through the diode at room temperature are noted down.
3. The oven is switched on and the temperature is allowed to increase up to 60º C.

4. As soon as the temperature reaches 60º C the oven is switched off. Sufficient time is allowed for the temperature of the diode to be established. The reading in the current meter is noted at that temperature.
5. As the temperature decreases the current through the diode decreases. As the temperature falls through steps of 2º C (2µ A) the corresponding current are noted down.
6. A graph is plotted taking $\frac{10^3}{T}$ on X – axis and $\log_{10} I$ on Y– axis. A straight line is obtained
7. The slope of the straight line is determined and using this in formula, Energy gap is calculated.

OBSERVATIONS:

$Room\ temperature$: ……………………………..ºC
$Current\ Io$: ……………………………..µ A

S. No.	Temperature ºC	Current I µ A	Temperature T ºK	$\frac{1}{T \times 10^{-3}}$ K^{-1}	Log $_{10}$ I
1.	60				
2.	58				
3.	56				
4.	54				
5.	52				
6.	50				
7.	48				
8.	46				
9.	44				
10.	42				
11.	40				
12.	38				
13.	36				
14.	34				
15.	32				

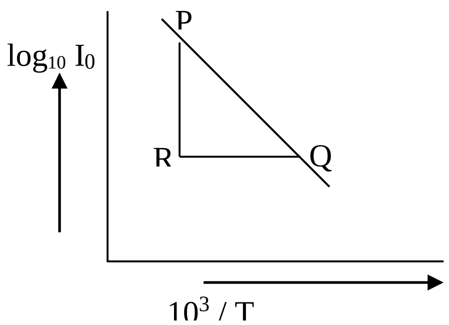
CALCULATIONS:

$$E_g = Slope\ of\ line \times 0.198\ eV$$

$$E_g = 0.198\ x\ (PR\ /\ RQ)\ eV$$

$$E_g = \cdots \ldots .\ eV$$

From the graph
PR = -----------
RQ = ------------



RESULTS: The energy band gap in germanium semiconductor is = ……………. eV.

The standard energy band gap in germanium semiconductor is = 0.7 eV.

Percentage error = --------%

PRECAUTIONS:

1. The diode and the thermometer are properly placed in the receptacles.
2. The maximum temperature of the diode is not allowed to go beyond 80º C.

VIVA – VOCE QUESTIONS

1. What do you mean by energy band gap?
2. How does it depend on the metals?
3. What is diode?
4. What is meant by valence band, conduction band and forbidden band?
5. How are the conductor, insulator and semi – conductor differentiated on the basis of energy band gap?
6. What are intrinsic and extrinsic semi – conductors?
7. What is a n – type semi – conductor?
8. What is a p – type semi - conductor?
9. Why does a semi – conductor behave like an insulator at absolute zero temperature?
10. What is a depletion layer?
11. What is order of thickness of a depletion layer?
12. What is meant by forward and reverse biasing of a function diode?
13. What is meant by potential barrier in semi – conductors?
14. What are the values of band gap in conductor, insulator and semi – conductor?

EXPERIMENT NO. :- 10 SONOMETER

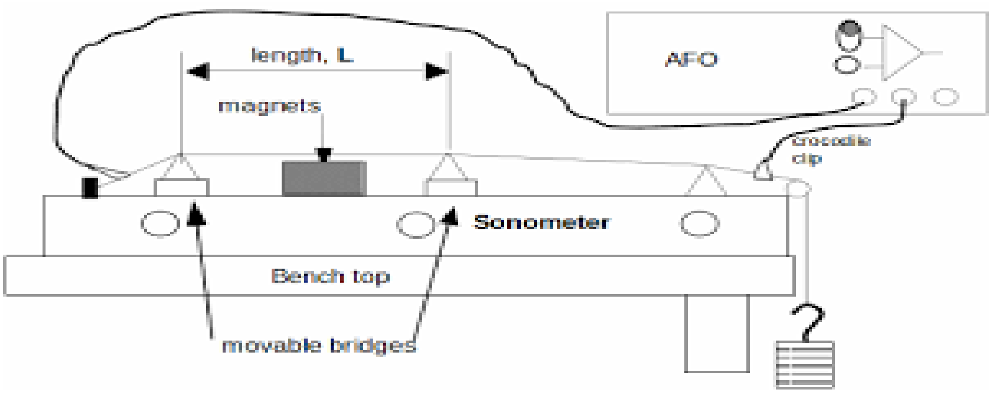
SONOMETER

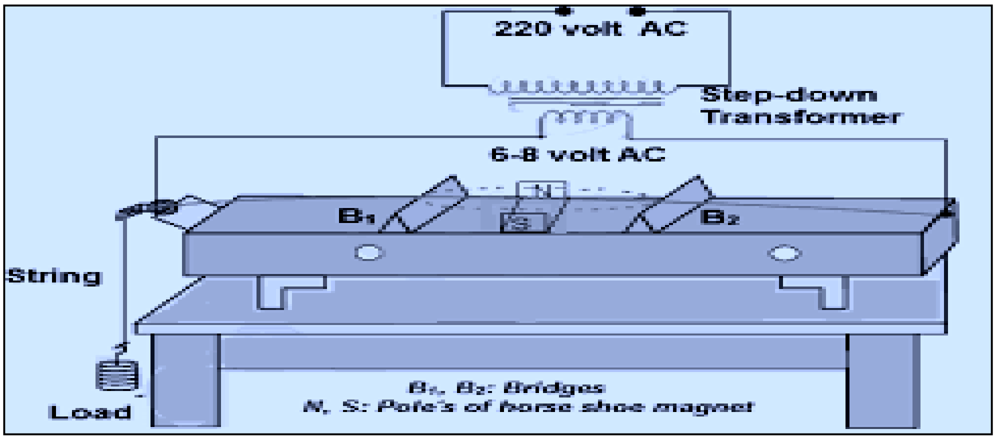
OBJECT: To determine the frequency of A. C. Mains with Sonometer.

APPARATUS:

1. A Sonometer with non-magnetic material wire,
2. 6 volt step- down transformer,
3. Permanent horse-shoe magnet or an electromagnet the material of the wire is magnetic; say iron and
4. Meter scale.

EXPERIMENTAL SETUP:





FORMULA USED: - The frequency of A. C. Mains is obtained from the

$$n = \frac{1}{2L}\sqrt{\frac{T}{m}}$$

When the Sonometer wire is of magnetic material (say iron)
T = tension applied to the Sonometer wire.
L = Length of the wire between the bridges when it vibrates with Maximum amplitude.
And m = mass per unit length of the Sonometer wire.

METHOD:-

1. First connections are made.
2. In case when the Sonometer wire is nonmagnetic, the horse shoe magnet is placed vertically near the center on the Sonometer board, such that the wire passes between the poles N and S of the magnet symmetrically and the magnetic field is horizontal. If Sonometer wire is of magnetic material then the electromagnet is so placed that its pole P is near to the middle of the wire between the bridges.

3. The current is switched on and the length l of the wire between the bridges is changed (by either one or both the bridges) but always satisfying the adjustment till it vibrates with maximum amplitude. The length of the wire is noted both the times while increasing and decreasing the length.
4. The tension T = Mg on the wire is changed by changing the load placed on the pan and the value of l is obtained each time.
5. The value of $\sqrt{M}/l$ is obtained for each set (M is the mass of the pan plus the mass of the weights placed on it) and its mean value is evaluated. The mean value of $\sqrt{M}/l$ can also be obtained by drawing a straight line Graph between $\sqrt{M}$ and l.
6. The mass per unit length of the wire is either found out by weighing a known length of the wire of evaluated from the formula m= $\pi r^2\rho$, where r is the radius of wire (which can be obtained by measuring its diameter with a screw gauge) and ρ is the density of the material of the wire. Frequency of A.C. mains is then calculated by using formula given above

OBSERVATION: Density of Sonometer wire (ρ) = 8.4 gm/cc
Value of g at Bareilly = 979.17 cm/s^2
Radius of Sonometer wire(r) (by screw gauge) = ... cm.
Mass per unit length (m) of Sonometer wire = $\pi r^2\rho$ = ...gm/cm

Sl.	**Tension applied**			**Length of the wire at resonance**			$\sqrt{M}/l$
	Mass of the pan (gm.)	**Mass placed on the pan (gm.)**	**Total Mass M (gm.)**	**Length increasing (cm.)**	**Length decreasing (cm.)**	**Mean l (cm.)**	**gm$^{1/2}$cm^{-1}**
1.	**50**	**0**	**50**				
2.	**50**	**50**	**100**				
3.	**50**	**100**	**150**				
4.	**50**	**150**	**200**				
5.	**50**	**200**	**250**				

Mean $\sqrt{M}/l$ **=..........................**

CALCULATION: $n = \frac{1}{2L}\sqrt{\frac{T}{m}}$ for magnetic material wire

$$n = \frac{\sqrt{M}}{2l}\sqrt{\frac{g}{m}}\ Cycle/sec$$

RESULT: Frequency of A.C. Mains = -------------------- Cycle / sec obtained by Sonometer.
Standard Frequency of A.C. Mains = 50 Cycle / sec
Percentage error = ---------------------

PRECAUTION:
1. The sonometer wire should be of uniform cross-section and kink free.
2. The friction at the pulley should be minimum.
3. The horse shoe magnet must be vertical. It be placed at the mid point of the vibrating wire.
4. The mass of the pan should also be taken into account for getting the value of the tension applied.

SOURCE OF ERROR: The following are the main source of error in the experiment.
1. Friction at the pulley.
2. Stiffness and non-uniformity of the wire.
3. Yielding of supports i.e. bridges.

VIVA – VOCE QUESTIONS

1. What is impedance of an A.C. circuit? Give its units.

2. Write an expression of power in a.c. circuit.
3. What is wattles current?
4. What is reactance?
5. What is the use of resonant circuits?
6. What is tuning fork?
7. What type of waves are produced in a vibrating tuning fork and how do you hear sound form it ?
8. What type of vibrations are produced in sonometer wire and the surrounding air ?
9. How are stationary waves produced in the wire?
10. When the tuning fork and the sonometer wire have been set in unison, a paper rider placed on the wire, falls off, on placing the fork on the sounding board, why?
11. What do you understand by resonance?
12. Is there any difference between frequency and pitch?