Ross Series

PHYSICS PRACTICALS

F. Sc. Part I & II

PHYSICS

PRACTICALS

for Intermediate Part I & II

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Preface

This notebook has been compiled for F.Sc. Physics students. For helping them in their practicals in the Physics laboratory. Theory and lengthy procedures are intentionally excluded.

Observations and calculations must be completed in the laboratory and get signed by the teacher before the student leaves the laboratory.

I have entered the readings in the blank tables, ***just for guidelines***. It's a new idea! These readings are not perfect. Some of these are taken from a normal student's practical notebook. If you want to take good marks in the exams, <u>you should take the readings by ***yourself.***</u>

I have made major diagrams of the apparatus in two dimensions, so that the students can ***reproduce the figures easily***.

There is no shortage of Physics practical note books in the market. But this notebook presents a different approach. No claim of originality is laid, but some pioneer work should be appreciated. Brevity is the soul of everything. It is hoped that the teacher and students will give the proper response for this work.

I have added new practicals in this manual, which are being introduced by the Education Department.

Useful suggestions will be appreciated to make this notebook more comprehensive and helpful.

July 2017. *Ross Nazir Ullah*

I never did anything worth doing by accident, nor did any of my inventions come by accident; they came by work. --Edison

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Method for plotting a graph

Step 1: ***Selecting independent and dependent variables***

a) Find the values, which are changing independently. It will be your independent variable.
b) Find the values that depend upon the independent variable. It will be your dependent variable.

Step 2: Making the Scale

a) Take difference of highest and lowest values.
b) Divide that difference by 6 for X-axis. Make that calculated difference a round figure. Write it down as the Scale on top right corner of the graph paper.
c) Divide the difference by 8 for Y-axis. Make that calculated difference a round figure. Write it down as the Scale on top right corner.

Step 3: Writing numbers along the Axes

a) Take lowest reading and write its round figure on the origin O.
b) Write down the values along the X-axis and Y-axis below the bold lines (big squares) progressively. That is, after adding the big division's value in each next value.

Step 4: Plotting the points

a) Firstly divide big division's scale by 10, to get small division's (or squares) value. Make small division's scale for X- and Y-axis.
b) Take a point from X-values. Find its position along big divisions for its whole figure part .
c) Multiply this point's fractional part with small division's scale. Then locate the position of the point along X-axis.
d) Take corresponding Y-value point. Repeat the above steps (b) & (c).
e) Locate intersection of both values in the graph paper. Mark this point with a dot and encircle it.
f) Similarly plot all the points.

Step 5: Drawing the Curve

i) For straight line graph

a) Take a transparent ruler.
b) Put the ruler in such a way that maximum points are symmetrical or pass through it.
c) Finally draw the line which is called Curve.

ii) If it is not straight line graph, then draw a smooth free hand curve passing symmetrically through large number of points.

Step 6: Writing Graph Title

Finally write down in bold letters, 'Graph between (say) A and B' on top location, starting from left side of the sheet.

Please note: *Method saves hours of wasted efforts.*

Date……………

Plotting graphs.

Graph No. 1:

Natural Nos.	x	1	2	3	4	5	6	7	8	9	10
Squares	y	1	4	9	16	25	36	49	64	81	100

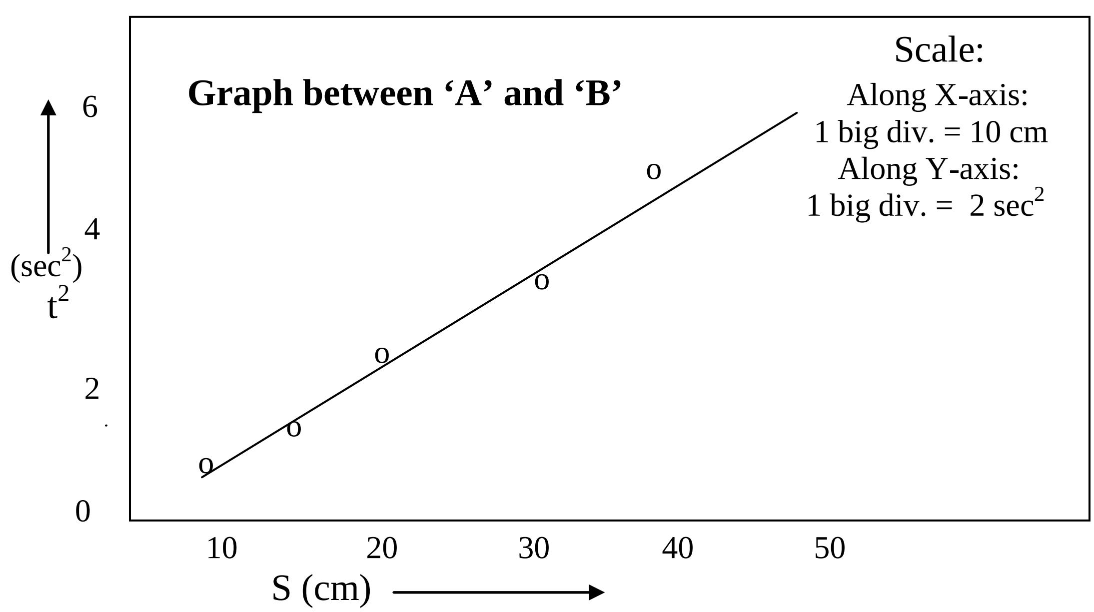
Graph No. 2:

Natural Nos.	x	1	2	3	4	5	6	7	8	9	10
Reciprocals	$1/x$	1	.5	.33	.25	.20	.17	.14	.13	.11	.1

Graph No. 3:

L	cm	71.3	81.3	91.3	101.3	111.3	121.3
T^2	sec^2	2.75	3.24	3.72	4.20	4.53	5.12

Typical graph:



Good start means that your half work is done!

Experiment A:

To plot a graph between:

i) Natural numbers and their squares.
ii) Natural numbers and their reciprocals,
iii) Given values of l and t^2

Materials:

Graph papers, lead pencil, rubber, sharpener, and transparent ruler.

Procedure:

1) *Draw the two axes with a sharp pencil, at right angles to each other taking a point O as origin at the left bottom corner of the graph paper.*
2) *Take independent variable (natural numbers) along X-axis and dependent (squares & reciprocals) along Y-axis.*
3) *Select suitable scales for both axes, so that all the graph paper would be covered.*
4) *Mark the scale on each axis, so that the value after every ten divisions is specified.*
5) *Start with a certain value represented along the X-axis and then locates the corresponding point along the Y-axis. Mark this point by a dot and encircle it. Similarly plot all points for different values of the two quantities.*
6) *Draw a smooth free hand curve passing symmetrically through large number of points. For straight line graph then draw with a transparent ruler so that maximum points pass through the line or symmetrical with it.*

Precautions:

1. A sharp pencil should be used.
2. Take along X-axis independent variable and along Y-axis dependent.
3. Small circles should be drawn around the plotted points.

Viva Voce:

Q.1 *What is a graph?*

Ans. A graph is a curve, which shows relation between an independent variable and its dependent variable.

Q.2 *What is variables?*

Ans. These are the quantities, which do not have fixed values.

Q.3 *What are independent and dependent variables?*

Ans. Independent variable is that which we vary independently and dependent variable is that which vary according to the variation depending upon independent variable.

Graph Illustration

Velocity time graph

V (m/s)	5.73	5.79	5.82	5.92	5.94
t(s)	0.66	0.76	0.86	0.95	1.05

(Read method for plotting a graph on page 7)

Step 1: taking t along X-axis & V along Y-axis

Step 2:

(big division)

$t \rightarrow \frac{1.05 - 0.66}{6} = \frac{0.39}{6} \cong \frac{0.40}{6} \cong 0.07 \cong 0.1 \Rightarrow$ B.d = 0.1 & s.d = 0.01

(small division)

$V \rightarrow \frac{5.94 - 5.73}{8} = \frac{0.21}{8} \cong \frac{0.2}{8} \cong .03 \Rightarrow$ B.d = 0.03 & s.d = 0.003

Scale:
Along X-axis:
1 big div = 0.1 sec
Along Y-axis:
1 big div = 0.03 m/s

Step 4:

$t_1 \rightarrow 0.6 + 6x.01 = .66$ & $V_1 \rightarrow 5.73$

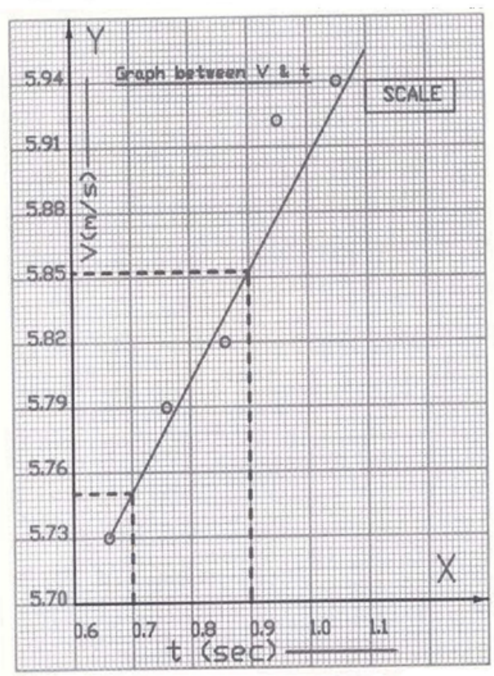
$t_2 \rightarrow 0.7 + 6x.01 = .76$ & $V_2 \rightarrow 5.79$

$t_3 \rightarrow 0.8 + 6x.01 = .86$ & $V_1 \rightarrow 5.82$

$t_4 \rightarrow 0.9 + 5x.01 = .95$ & $V_1 \rightarrow 5.91 + 4x.003 = 5.921 > 5.92$

$t_5 \rightarrow 1 + 5.5\ x.01 = 1.055 < 1.06$ & $V_1 \rightarrow 5.94$ (a little lower point)

(5 & ½ s.d) (a little higher point)



Evaluation

Finding :

average acceleration,

$a_{av} = \Delta V / \Delta t$

$= \frac{5.852 - 5.751}{0.9 - 0.7} = \frac{0.101}{0.2}$

$= 0.5\ cm/sec^2$

Note: Do not depend upon these calculations, do your own calculations.

Natural numbers & their squares

N	1	2	3	4	5	6	7	8	9	10
N^2	1	45	9	16	25	36	49	64	81	100

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 2
Along Y-axis:
1 big div = 15

Step 1: taking N along X-axis & N^2 along Y-axis

Step 2:

$N \rightarrow \frac{10-1}{6} = \frac{9}{6} \cong 2 \Rightarrow$ B.d = 2 & s.d = 0.2

$N^2 \rightarrow \frac{100-1}{8} = \frac{99}{8} = 12.4 \cong 15 \Rightarrow$ B.d. = 15 & s.d. = 1.5

Step 4:

$N_1 \rightarrow 0 + 5x.2 = 1$ & $N_1^2 \rightarrow 0 + 2/3 \text{ x } 1.5 = 1$

$N_2 \rightarrow 2$ & $N_2^2 \rightarrow 0 + 3 \text{ x}1.5\ 4.5 > 4$

$N_3 \rightarrow 2 + 5x.2 = 3$ & $N_3^2 \rightarrow 0 + 6\text{x } 1.5 = 9$

$N_4 \rightarrow 4$ & $N_4^2 \rightarrow 15 + 2/3 \text{ x}1.5 = 16$

$N_5 \rightarrow 4 + 5 \text{ x}.2 = 5$ & $N_5^2 \rightarrow 15 + 7 \text{ x } 1.5 = 25.5 > 25$

$N_6 \rightarrow 6$ & $N_6^2 \rightarrow 30 + 4\text{x } 1.5 = 36$

$N_7 \rightarrow 6 + 5 \text{ x}.2 = 7$ & $N_7^2 \rightarrow 45 + 3 \text{ x } 1.5 = 49.5 > 49$

$N_8 \rightarrow 8$ & $N_8^2 \rightarrow 60 + 3 \text{ x}1.5 = 64.5 > 64$

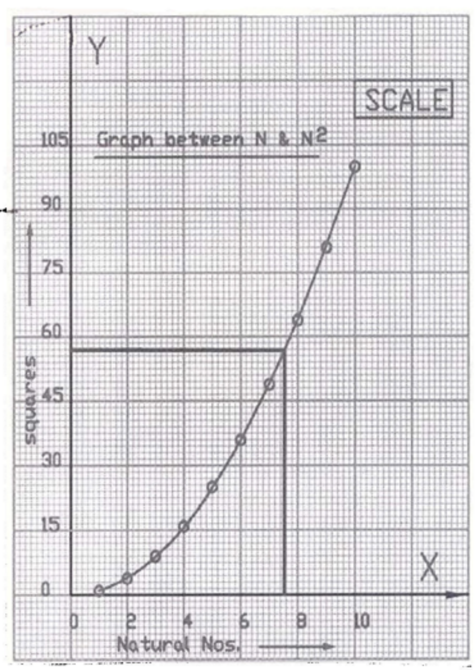
$N_9 \rightarrow 8 + 5 \text{ x }.2 = 9$ & $N_9^2 \rightarrow 75 + 4\text{x } 1.5 = 81$

$N_{10} \rightarrow 10$ & $N_{10}^2 \rightarrow 90 + 6.6 \text{ x } 1.5 = 99.9 < 100$

How to find s.d. multiplier

$$\frac{\text{Plot value} - \text{B.d. value}}{\text{s.d.}}$$

$$= \frac{100-90}{1.5} = \frac{10}{1.5} = 6.66$$



Evaluation

Finding:

Value of $(7.5)^2$ from graph:

$N_{7.5} \rightarrow 57$

Value of $(7.5)^2$ from calculation:

$(7.5)^2 = 56.25$

The difference is 0.75

Your calculations and result should be better than this.

Natural Nos. & their reciprocals

N	1	2	3	4	5	6	7	8	9	10
1/N	1	0.50	0.33	0.25	0.20	0.17	0.14	0.13	0.11	0.10

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 2
Along Y-axis:
1 big div = 0.15

Step 1: taking N along X-axis & 1/N along Y-axis

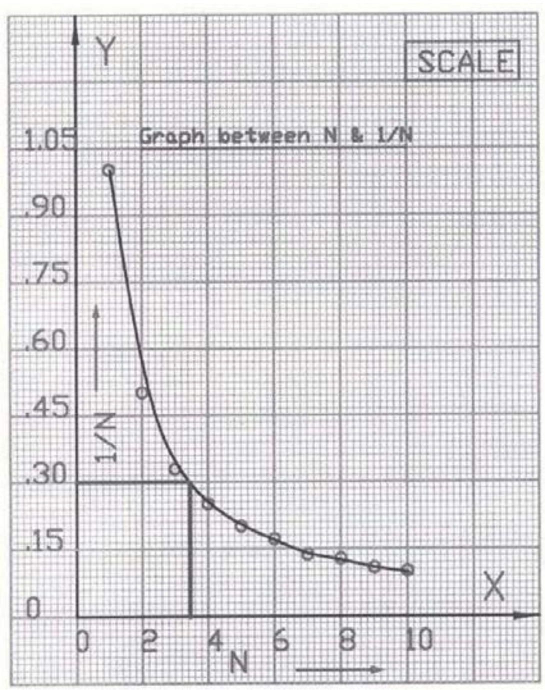
Step 2:

N $\rightarrow \frac{10-1}{6} = \frac{9}{6} \cong 2 \Rightarrow$ B.d = 2 & s.d = 0.2

N^2 $\rightarrow \frac{1-0.1}{8} = \frac{0.9}{8} = .15 \Rightarrow$ B.d. = 0.15 & s.d. = 0.015

Step 4:

$N_1 \rightarrow 0 + 5x.2 = 1$ & $1/N_1 \rightarrow .9 + 7x.015 < 1$
$N_2 \rightarrow 2$ & $1/N_2 \rightarrow .45 + 3.5\ x.015 > .5$
$N_3 \rightarrow 2 + 5x.2 = 3$ & $1/N_3 \rightarrow .3 + 2x.015 = .33$
$N_4 \rightarrow 4$ & $1/N_4 \rightarrow .15 + 7x.015 < .25$
$N_5 \rightarrow 4 + 5\ x.2 = 5$ & $1/N_5 \rightarrow .15 + 3\ x\ .015 > .20$
$N_6 \rightarrow 6$ & $1/N_6 \rightarrow .15 + 1.5x.015 = .17$
$N_7 \rightarrow 6 + 5\ x.2 = 7$ & $1/N_7 \rightarrow 0 + 9\ x.015 < .135$
$N_8 \rightarrow 8$ & $1/N_8 \rightarrow 0 + 9\ x.015 > .135$
$N_9 \rightarrow 8 + 5\ x\ .2 = 9$ & $1/N_9 \rightarrow 0 + 7x.015 < .11$
$N_{10} \rightarrow 10$ & $1/N_{10} \rightarrow 0 + 7\ x\ .015 > .10$



Evaluation

Finding:

Value of (3.4) from graph:

$N_{3.4} \rightarrow$ (1/N) = 0.3

It is not must that you follow my method of manipulation, you may adopt your own.

Simple Pendulum graph

l (cm)	70	80	90	100	110
T^2 (s^2)	2.89	3.23	3.62	4.11	4.41

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 10 cm
Along Y-axis:
1 big div = 0.2 sec^2

Step 1: taking l along X-axis & T^2 along Y-axis

Step 2:

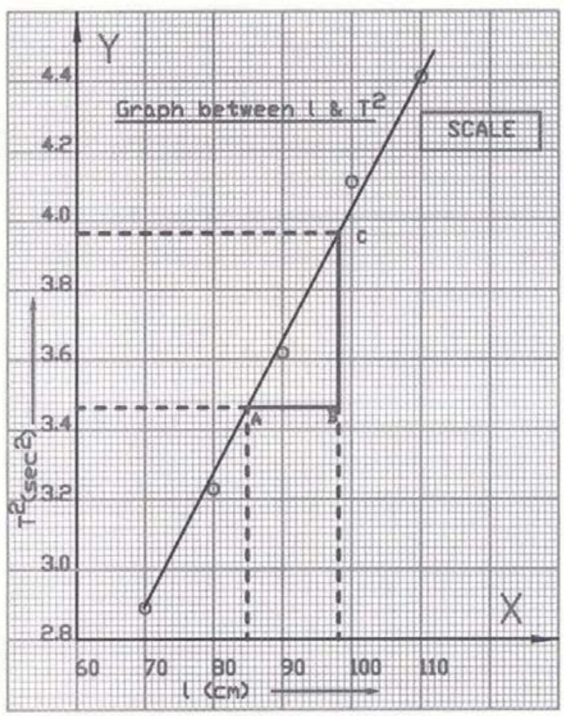
$l \rightarrow \frac{110-70}{6} = \frac{40}{6} \cong 7 \Rightarrow$ B.d = 10 & s.d = 1.0

$T^2 \rightarrow \frac{4.41-2.89}{8} = \frac{1.52}{8} \cong 0.2 \Rightarrow$ B.d. = 0.2 & s.d. = 0.02

Step 4:

$l_1 \rightarrow 70$ & $T_1^2 \rightarrow 2.8 + 4.5 \text{ x } .02 = 2.88$
$l_2 \rightarrow 80$ & $T_2^2 \rightarrow 3.2 + 1.5 \text{ x } .02 = 3.23$
$l_3 \rightarrow 90$ & $T_3^2 \rightarrow 3.6 + 1\text{x}.02 = 3.62$
$l_4 \rightarrow 100$ & $T_4^2 \rightarrow 4 + 5.5\text{x}.02 = 4.11$
$l_5 \rightarrow 110$ & $T_5^2 \rightarrow 4.4 + ½ \text{ x } .02 = 4.41$

Evaluation



Finding:

1) slope of the graph:

slope = tan CAB = BC/AB

= 0.5 /13 = 3.8 sec^2 /cm

2) length of second's pendulum:

$T^2 = 4 \rightarrow l = 100$ cm

3) length corresponding to 1.9 sec:

$T_{1.9 \text{ sec}} \rightarrow T^2_{8.61} \rightarrow l = 90.5$ cm

We define slope of a line as tan θ, where θ is the inclination of a line.

Helical Spring graph

x (cm)	12.2	15.3	18.4	21.0	23.5
T^2 (s^2)	0.55	0.67	0.76	0.86	0.95

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 2 cm
Along Y-axis:
1 big div = 0.05 sec^2

Step 1: taking x along X-axis & T^2 along Y-axis

Step 2:

$x \rightarrow \frac{23.5 - 12.2}{6} = \frac{11.3}{6} \cong 2 \Rightarrow$ B.d = 2 & s.d = 0.2

$T^2 \rightarrow \frac{0.95 - 0.55}{8} = \frac{0.4}{8} = .05 \Rightarrow$ B.d. = 0.05 & s.d. = 0.005

Step 4:

$x_1 \rightarrow 12 + 1x.2 = 12.2$ & $T_1^2 \rightarrow .55$
$x_2 \rightarrow 14 + 6.5x.2 = 15.3$ & $T_2^2 \rightarrow .65 + 4x.005 = .67$
$x_3 \rightarrow 18 + 2x.2 = 18.4$ & $T_3^2 \rightarrow .75 + 2x.005 = .76$
$x_4 \rightarrow 20 + 5x.2 = 21$ & $T_4^2 \rightarrow .85 + 2x.005 = .86$
$x_5 \rightarrow 22 + 7.5\,x.2 = 23.5$ & $T_5^2 \rightarrow .95$

Evaluation

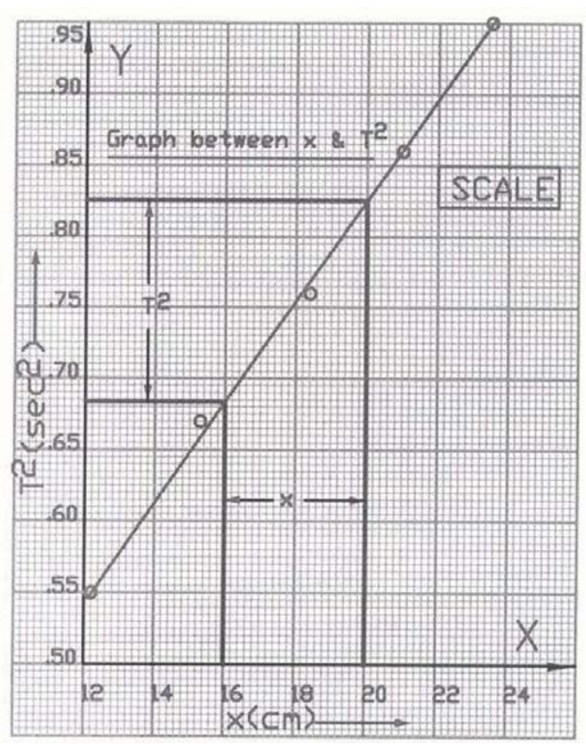
Finding:

'g' from graph :

$g = 4\pi^2 (x/T^2)$

$= 4\pi^2 (4/0.14)$

$= 1126$ cm /sec^2



Not a good result. Sources of error might be in readings, or plotting the graph.

Law of length graph

From the following readings, verify law of length:

ν (Hz)	512	480	384	280
l (m)	0.12	0.129	0.16	0.23

For the verification of the law taking 1 /*l* ;

ν (Hz)	512	480	384	280
$1/l$ (m^{-1})	8.33	7.75	6.25	4.35

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 40 Hz
Along Y-axis:
1 big div = 0.50 cm^{-1}

Step 1: taking ν along X-axis & $1/l$ along Y-axis

Step 2:

$$\nu \rightarrow \frac{512 - 280}{6} = 38.66 \cong 40 \Rightarrow \text{B.d} = 40 \ \& \ \text{s.d} = 4$$

$$1/l \rightarrow \frac{8.33 - 4.35}{8} = 0.49 \cong 0.50 \Rightarrow \text{B.d.} = 0.50 \ \& \ \text{s.d.} = 0.05$$

Step 4:

$\nu_1 \rightarrow 500 + 3 \times 4 = 512$ & $1/l_1 \rightarrow 8.20 + 2.6 \times .05 = 8.33$

$\nu_2 \rightarrow 460 + 5 \times 4 = 480$ & $1/l_2 \rightarrow 7.70 + 1 \times .05 = 7.75$

$\nu_3 \rightarrow 380 + 1 \times 4 = 384$ & $1/l_3 \rightarrow 6.20 + 1 \times .05 = 6.25$

$\nu_4 \rightarrow 260 + 5 \times 4 = 280$ & $1/l_4 \rightarrow 4.20 + 3 \times .05 = 4.35$

Evaluation

Finding:

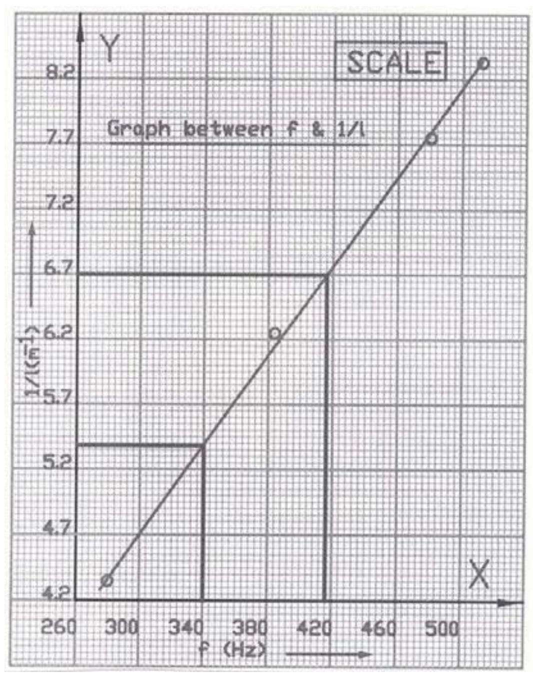
1) Relation between ν & $1/l$:

Graph between
ν & $1/l$ is a straight line

2) Finding slope of graph :

$$\frac{6.7 - 5.38}{420 - 340} = \frac{1.32}{80}$$

$= 0.0165$



ν *& l graph will be decreasing straight line, showing inversely proportional to each other.*

Law of Tension graph

From the following readings, verify law of tension:

f (Hz)	518	480	384	350	300
T (N)	44.1	39.2	24.3	19.6	14.5

For the verification of the law taking $\sqrt{T}$;

f (Hz)	518	480	384	350	300
$\sqrt{T}$ ($\sqrt{N}$)	6.64	6.26	4.93	4.43	3.80

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 40 Hz
Along Y-axis:
1 big div = 0.4 $\sqrt{N}$

Step 1: taking f along X-axis & $\sqrt{T}$ along Y-axis

Step 2:

f → $\frac{518 - 300}{6}$ = 36.33 ≅ 40 ⇒ B.d = 40 & s.d = 4

$\sqrt{T}$ → $\frac{6.64 - 3.80}{8}$ = 0.355 ≅ 0.4 ⇒ B.d. = 0.4 & s.d. = 0.04

Step 4:

f_1 → 500 + 4.5 x4 = 518 & $\sqrt{T_1}$ → 6.4 + 6 x .04 = 6.64

f_2 → 480 & $\sqrt{T_2}$ → 6 + 6.5 x .04 = 6.26

f_3 → 380 + 1 x 4 = 384 & $\sqrt{T_3}$ → 4.8 + 3.25 x.04 = 4.93

f_4 → 340 + 2.5 x 4 = 350 & $\sqrt{T_4}$ → 4.40 + 0.75 x.04 = 4.43

f_5 → 300 & $\sqrt{T_5}$ → 3.6 + 5 x .04 = 3.80

Evaluation

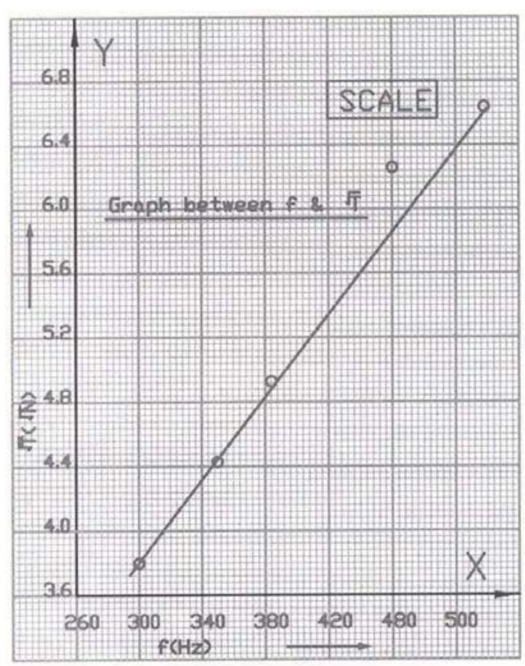
1) Verification of the law:

Since graph between

f & $\sqrt{T}$ is a straight line,

so f ∝ $\sqrt{T}$,

which is Law of Tension.



Increasing straight line shows that both values are directly proportional to each other.

p-q graph

p (cm)	15.2	20.1	22.3	24.2	30.3	36.2
q (cm)	30.1	20.3	18.1	16.8	15.2	14.1

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 5 cm
Along Y-axis:
1 big div = 5 cm

Step 1: taking p along X-axis & q along Y-axis

Step 2:

p → $\frac{36.2 - 15.2}{6}$ = 3.5 ≅ 5 ⇒ B.d = 5 & s.d = 0.5

(making equal to x-scale)

q → $\frac{30.1 - 14.1}{8}$ = 2 ≅ 5⇒ B.d. = 5 & s.d. = 0.5

Step 4:

p_1 → 15 + ½ x.5 = 15.25 > 15.2 & q_1 → 30 + 1/5 x .5 = 30.1
p_2 → 20 + 1/5 x .5 = 20.1 & q_2 → 20 + .6 x .5 = 20.3
p_3 → 20 + 4.6 x .5 = 22.3 & q_3 → 15 + 6.2 x.5 = 18.1
p_4 → 20 + 8.8 x .5 = 24.2 & q_4 → 15 + 3.6 x.5 = 16.8
p_5 → 30 + 0.6 x .5 = 30.3 & q_5 → 15 + 0.4 x .5 = 15.2
p_6 → 35 + 2.4 x .5 = 36.2 & q_6 → 10 + 8.2 x .5 = 14.1

Evaluation

Finding:

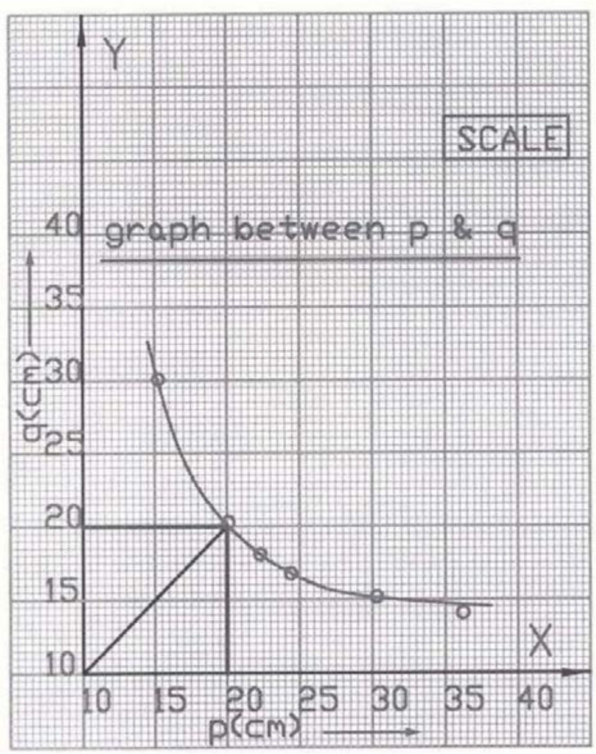
1) intercepts on x & y-axis:

intercepts on x-axis = 20 cm

& intercepts on y-axis = 20cm

2) focal length of the lens:

f = 20 /2 = 10 cm



We define x-intercept of a curve is the x-coordinate of the point of intersection of the curve with the x-axis. Similarly y-intercept is defined.

(p+q) & pq graph

(p+q) cm	50.00	48.00	49.20	51.00	54.20
pq (cm^2)	600.00	575.00	578.00	612.40	644.00

(Read method for plotting a graph on page 7)

Step 1: taking (p+q) along X-axis & pq along Y-axis

Step 2:

$(p+q) \rightarrow \frac{54.2 - 48.0}{6} = 1.03 \cong 1 \Rightarrow$ B.d = 1 & s.d = 0.1

$pq \rightarrow \frac{644.0 - 575}{8} = 8.6 \cong 10 \Rightarrow$ B.d. = 10 & s.d. = 1

Scale:
Along X-axis:
1 big div = 1 cm
Along Y-axis:
1 big div =10 cm^2

Step 4:

$(p+q)_1 \rightarrow 50$ & $pq_1 \rightarrow 600$

$(p+q)_2 \rightarrow 48$ & $pq_2 \rightarrow 570 + 5 \times 1 = 575$

$(p+q)_3 \rightarrow 49 + 2 \times .1 = 49.2$ & $pq_3 \rightarrow 570 + 8 \times 1 = 578$

$(p+q)_4 \rightarrow 51$ & $pq_4 \rightarrow 610 + 2.4 \times 1 = 612.4$

$(p+q)_5 \rightarrow 54 + 2 \times .1 = 54.2$ & $pq_5 \rightarrow 640 + 4 \times 1 = 644$

Evaluation

Finding:

1) slope of the graph:

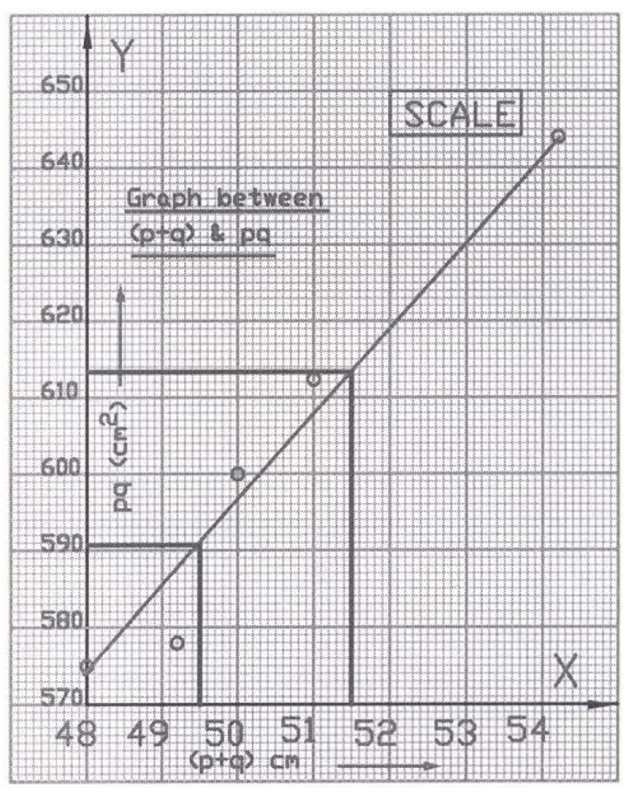
$$\text{slope} = \frac{614.25 - 590.75}{51.5 - 49.5}$$

$$= \frac{23.5}{2} = 11.75$$

2) focal length of the lens:

The focal length will be equal to the slope ,

$= f = 11.75$cm



Investigate the manipulations of how 'f' is equal to the slope in this graph.

1/p & 1/q graph

$1/p\ (cm^{-1})$	0	0.02	0.04	0.058	0.07	0.082
$1/q\ (cm^{-1})$	0.082	0.054	0.04	0.02	0.01	0.002

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 0.02 cm^{-1}
Along Y-axis:
1 big div = 0.01 cm^{-1}

Step 1: taking 1/p along X-axis & 1/q along Y-axis

Step 2:

$1/p \rightarrow \frac{0.082 - 0}{6} = 0.014 \cong 0.02 \Rightarrow$ B.d = 0.02 & s.d = 0.0.002

$1/q \rightarrow \frac{0.082 - 0.002}{8} = 0.01 \Rightarrow$ B.d. = 0.01 & s.d. = 0.001

Step 4:

$1/p_1 \rightarrow 0$ & $1/q_1 \rightarrow 0.08 + 2 \times .001 = 0.082$

$1/p_2 \rightarrow 0.02$ & $1/q_2 \rightarrow 0.05 + 4 \times .001 = 0.054$

$1/p_3 \rightarrow 0.04$ & $1/q_3 \rightarrow 0.04$

$1/p_4 \rightarrow 0.04 + 9 \times .002 = 0.058$ & $1/q_4 \rightarrow 0.02$

$1/p_5 \rightarrow 0.06 + 5 \times .002 = 0.07$ & $1/q_5 \rightarrow 0.01$

$1/p_6 \rightarrow 0.08 + 1 \times .002 = 0.082$ & $1/q_6 \rightarrow 0 + 2 \times .001 = 0.002$

Evaluation

Finding:

1) intercepts on x & y-axis:

intercepts on x-axis = 0.08 cm

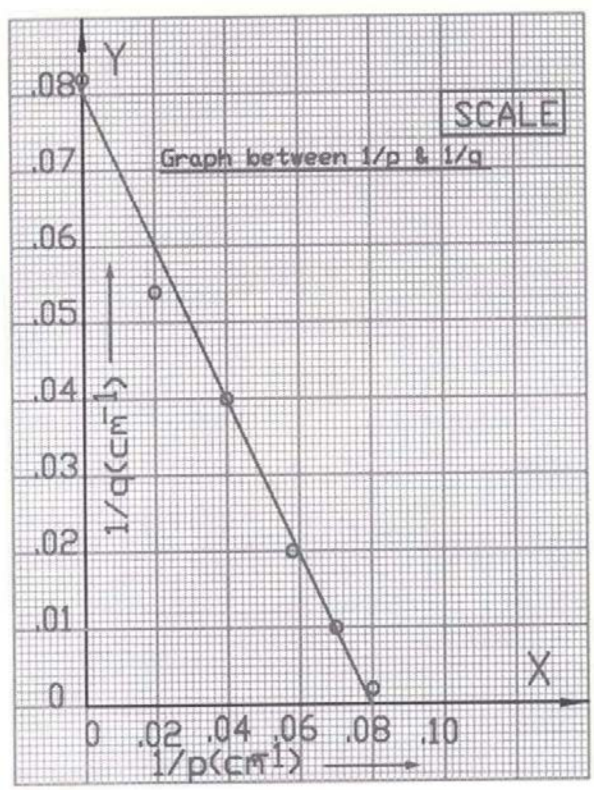
& intercepts on y-axis =0.08cm

2) focal length of the lens:

focal length of the lens is

reciprocal of either intercept

f = 1/ 0.08 = 12.5 cm



In the graph, what conclusion you make from the decreasing curve?

Young's Modulus graph

F (kg)	1	2	3	4	5
l (mm)	0.25	0.55	0.83	1.05	1.36

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 1 kg
Along Y-axis:
1 big div = 0.2 mm

Step 1: taking F along X-axis & l along Y-axis

Step 2:

$F \rightarrow \frac{5-1}{6} = \frac{4}{6} \cong .7 \cong 1 \Rightarrow$ B.d = 1 & s.d = 0.1

$l \rightarrow \frac{1.36 - 0.25}{8} = \frac{1.11}{8} = 0.14 \Rightarrow$ B.d. = 0.2 & s.d. = 0.02

Step 4:

$F_1 \rightarrow 1$ & $l_1 \rightarrow .2 + 2.5 \times .02 = .25$

$F_2 \rightarrow 2$ & $l_2 \rightarrow .4 + 7.5 \times .02 = 0.55$

$F_3 \rightarrow 3$ & $l_3 \rightarrow .8 + 1.5 \times .02 = 0.83$

$F_4 \rightarrow 4$ & $l_4 \rightarrow 1.0 + 2.5 \times .02 = 1.05$

$F_5 \rightarrow 5$ & $l_5 \rightarrow 1.2 + 8 \times .02 = 1.36$

Evaluation

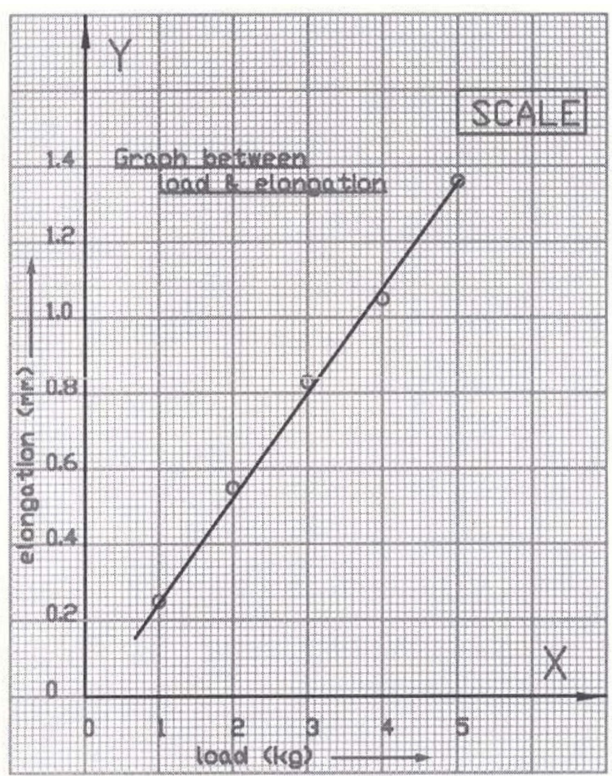
Finding:

1) Relation between F & l:

The curve of the graph shows,

that $F \propto l$,

which verify the relation for Young's modulus,



A normal student's value will not so perfect, due to neglecting the sources of error.

Graph Exercises

Draw the following graphs between the parameters and deduce the given requirements.

(1)

F(dynes)	50 x 980	100 x 980	150 x 980	200 x 980	250 x 980
x (cm)	2.9	5.8	8.4	11.3	14.8

i) What inference you draw from the graph?
ii) Determine the spring constant.

(2)

V(cm/sec)	3	5	7	9	11
KE(Joules)	22	75	165	295	489

i) Determine the slope of the graph.
ii) Find the value of KE, when velocity is 7.5 cm/sec.

(3)

v (cm s^{-1})	438	452	458	469	475	486
t (sec)	12	15	20	24	30	36

i) Find average acceleration at t = 10, 22 & 35 seconds.
ii) Which type of acceleration, the graph shows?

(4)

S (cm)	100	125	142	153	165
t (sec^2)	2.36	2.82	2.91	3.21	3.43

i) Find the average velocity at, t = 2.5, 2.8 & 3.0 seconds.
ii) The relation between S & t from the slope.

(5)

1/p(cm^{-1})	0.002	0.03	0.04	0.06	0.07
1/q(cm^{-1})	0.074	0.052	0.039	0.023	0.012

i) Determine focal length of the lens.
ii) Write down its units.

(6)

l (cm)	60	65	70	75	80	85
T^2 (sec^2)	2.10	2.58	2.62	3.15	3.65	3.82

i) What is the slope of the graph?
ii) Calculate length of second's pendulum.

(7)

t ^oC	15	30	40	50	60	70
Surface tensionT(dynes/cm)	72.4	71.2	69.7	68.1	65.5	64.1

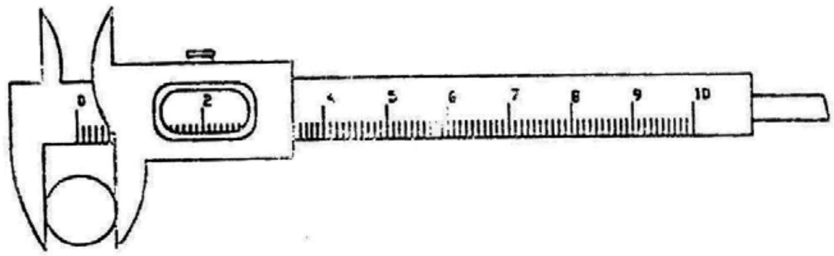
i) Show the relation between temperature and surface tension.
ii) Find surface tension at 53 ^oC.

You should be able to perform these exercises, if you made all previous 11 graphs

Date………..

Expt: Use of Vernier Calipers.

Vernier Calipers:



Observations and Calculations:

Value of the smallest scale division = x = 0.1 cm
No. of divisions on the vernier scale = y = 10
Vernier constant (V.C.) = x/y = 0.1/10 = 0.01 cm
Zero error = i) ± .....cm , ii) ± .....cm , iii) ± .....cm
Mean zero error = ... cm
Zero correction = ... cm

No. of obs.	Quantity	Main scale reading	Vernier divisions coinciding with any main scale division	Fraction to be added	Total reading observed	Total reading corrected
		x_1	N	Δx = n x V.C.	$x = x_1 + \Delta x$	x ± zero correction
		cm		cm	cm	cm
1	Length	*3.8*	*5*	*5 x .01= .05*	*3.85*	*3.85 + 0 = 3.85*
2						
3						
1	Diameter	*1.2*	*3*	*3 x .01 =.03*	*1.23*	*1.23 + 0 = 1.23*
2						
3						

Mean length of cylinder = L = _________ cm
Mean diameter of cylinder = D = ______ cm
Radius of the cylinder R = D/2 = ______ cm
Volume of the cylinder = V = $\pi R^2 L$ = ______ cm^3

Note: The above-tabulated values are just for guideline. Take your own readings.

Find the Internal volume of glass beaker with the help of Vernier calipers. Cross check with 100 ml beaker.

Experiment No. 1:

To find the volume of a cylinder using Vernier calipers.

Apparatus:

Solid cylinder, Vernier calipers, and half meter rod.

Construction:

Vernier calipers consists of a steel bar of two scales. A fixed scale called main scale and a moveable scale called vernier scale. Usually vernier scale has 10 divisions equal to 9 small divisions of main scale. Lower jaws are for measuring the length or diameter and upper jaws are for measuring internal diameter. Backside strip is for measuring depth of an object.

Procedure:

1) *Find the vernier constant of the given vernier calipers.*
2) *Determine its zero error if any.*
3) *Place the cylinder length-wise between the two jaws. Read the main scale division just to the left of the zero of the vernier.*
4) *Locate the number of vernier divisions coinciding with any main scale division. Note these readings thrice.*
5) *Complete the table up to the last column.*
6) *In the same way find the diameter of the cylinder from different positions. Taking two reading at right angles on each position.*
7) *Calculate mean values of the length and the diameter and find the radius of the cylinder.*
8) *Find out the volume of the cylinder from the formula.*

Precautions:

1. Take at least three readings for each measurement.
2. The jaws of the vernier should not be pressed to hard.
3. Vernier divisions should be read clearly, may be with some magnifying glass.

Viva Voce:

Q.1 *What is vernier constant?*

Ans. It is the smallest measurement which a vernier can read.

Q.2 *What is a vernier?*

Ans. A device used to measure the fraction of smallest scale divisions up to tenth part of a centimeter.

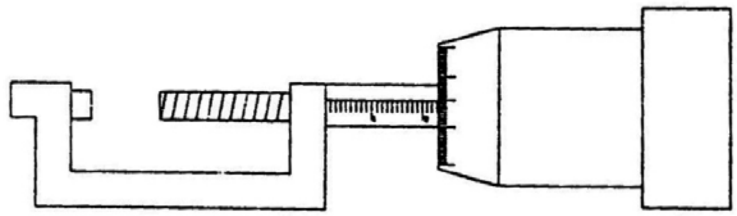
Q.3 *Who invented Vernier calipers?*

Ans. A French mathematician, Pierre Vernier invented it.

Date…………

Expt: Use of Screw gauge.

Screw gauge:



Observations and Calculations:

Pitch of the screw gauge = x = 1 mm

No. of divisions on circular scale = y = 100

Least count (L.C.) = x / y = 1/100 = 0.01 mm

Zero error = i) + .05, ii) +.07 , iii) + .06

Mean zero error = + .06

Zero correction (Z.C.) = - .06

No. of obs.	Quantity	Linear scale reading	Circular scale reading	Fraction to be added	Diameter	
					Observed	Corrected
		R′	N	x = n x L.C.	R = R′ + x	R $\pm$ Z.C.
		mm		mm	mm	mm
1	Wire	1	59	59 x .01 =.59	1.59	1.53
2						
3						
1	Small sphere	3	87	87 x .01 = .87	3.87	3.81
2						
3						

a) Mean diameter = D = ----- mm

Radius r = D/2 = ----- mm

Area of cross-section of the wire = A = πr^2 = ----- mm^2

b) Mean diameter of small sphere = d = ----- mm

Radius = r = d/2 = ----- mm

Volume of small sphere = V = $4/3\, \pi r^3$ = ----- mm^3

Archimedes tomb was marked by the figure of a sphere inscribed in a cylinder.

Determine the diameter of a thinnest possible wire. [With screw gauge a measurement up to 0.01 mm is possible.]

Experiment No. 2:

To find area of cross-section of a wire and volume of a small sphere using micrometer screw gauge.

Apparatus:

Micrometer screw gauge, small sphere, fine wire, and half-meter rod.

Construction:

It consists of U-shaped metallic frame having one end fixed and the other end, moveable having a metal cylinder rod marked with a horizontal line over which a fixed scale is marked, called Main scale. A cap is fitted over cylinder, carries a moveable scale with 100 divisions around it, called circular scale.

Procedure:

1) *Find the pitch and least count of screw gauge.*
2) *Find the zero error, and determine the sign of zero correction.*
3) *Place the wire in the gap AB (see the fig.) and turn the screw till the wire is gently pressed. Note the reading of the linear as well as the circular scale in the table.*
4) *Complete the table up to last column. Take the readings from different places of the wire.*
5) *Calculate mean diameter of the wire.*
6) *Repeat the process for the given small sphere.*
7) *Calculate mean diameter of the sphere.*
8) *Find the radius and hence area of cross-section of the wire. Also the volume of the sphere by applying the formula.*

Precautions:

1. The screw should not be pressed too hard.
2. The screw should be turned in the same direction.
3. Take two readings at right angles at each point of the wire.

Viva Voce:

Q.1 *What is the least count of Screw gauge?*

Ans. The shortest distance which can be measured by it.

Q.2 *What is the 'pitch' of the screw gauge?*

Ans. It is the distance between the two successive threads of linear scale.

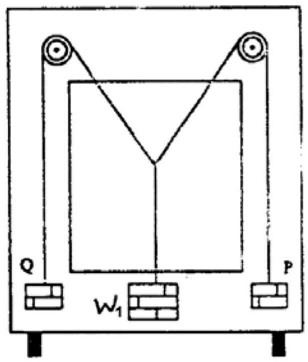
Q.3 *How screw gauge take linear readings from its circular movement?*

Ans. The forward (or backward) movement of the screw is directly proportional to linear movement of the head of the screw gauge.

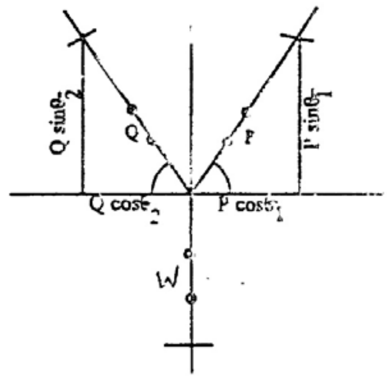
Date…………

Expt: Addition of vectors by Gravesand's apparatus.

The apparatus:



Geometrical work diagram :



Observations and Calculations:

No. of obs.	Forces		Angles		Vertical components of forces		Resultant R =	Unknown weight w = R
	P	Q	θ_1	θ_2	P $\sin\theta_1$	Q $\sin\theta_2$	P $\sin\theta_1$ + Q $\sin\theta_2$	
	g-wt	g-wt	degree	degree	g-wt	g-wt	g-wt	g-wt
1	30	30	49	48	22.65	22.29	44.94	44.94
2								
3								

Mean w = ----- g-wt

Note: For the sake of convenience, we have taken gram-weight (gm-wt), a unit of force, as a laboratory unit of force. Instead to take grams and multiply with a factor 980 to get dynes.

1. Find out unknown weight by end-to-end and trigonometric method.
2. In Gravesand's apparatus, put known weights in the center (resultant position) and in one of the side. Calculate from vector addition one of the unknown side weight.

Experiment No. 3:

To find the unknown weight of a body by the method of vector addition of forces.

Apparatus:

Gravesand's apparatus, slotted weights with hangers, white paper sheet, drawing pins, mirror strip, set squares, Dee, thread, half meter rod.

Procedure:

1) *Set the board vertical. Test pulleys for no friction.*
2) *Take three pieces of thread and knot them together.*
   Attach one hanger to each of their free ends.
3) *Load the hangers with suitable weights, and pass two of the hangers through the pulleys.*
4) *Attach unknown weight with middle thread.*
5) *Fix a sheet of paper on the board with drawing pins.*
6) *Mark two points for each thread, looking in such a direction that the thread and its image are coincident to each other.*
7) *Remove the paper. Join the points to produce three lines.*
8) *Note the weights. Repeat twice by taking different set of weights.*
9) *Choose a suitable scale. Do geometrical work as shown in fig. (b).*
10) *Complete all columns of the table, which includes taking rectangular components of vectors **P** and **Q**.*

Precautions:

1. Pulleys should be frictionless.
2. Preferably heavy weights should be used.
3. The weights so chosen that the knot comes in the middle.

Sources of Error:

1. The weights might be touching the board.
2. The board might not be vertical and stable.
3. The thread might be of low quality.

Viva Voce:

Q. 1: *What is 'Resultant force' ?*

Ans. It is a single force equivalent to the combined effect of all the forces.

Q. 2: *What happens to the components P_x and Q_x ?*

Ans. These components are equal and opposite and hence cancel each other.

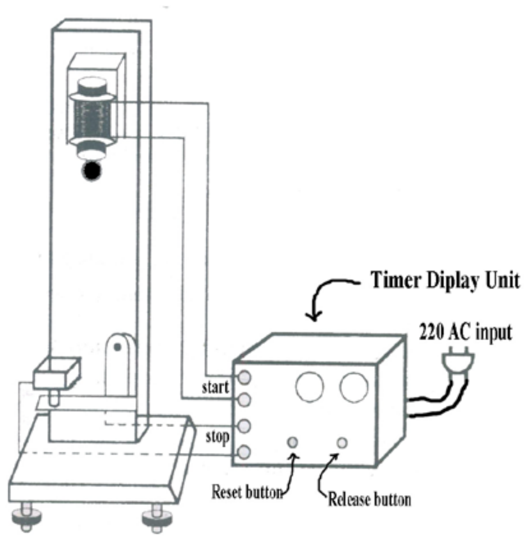
Q. 3: *How is force represented on a diagram?*

Ans. A straight line represents force. The length of this line represents the magnitude of the force and its angle gives the direction of the force.

Date…………

Expt: 'g' by free fall method.

Free-fall Apparatus for ticker timer:



Observations and Calculations:

No. of obs.	Height fallen S	Time of fall t	t^2	$g = \frac{2S}{t^2}$
	cm	s	s^2	cm/s^2
1	74.3	0.40	0.16	928.75
2				
3				
4				
5				

Mean 'g' = ----- cm / s^2

Calculating g from the graph value of $((S / t^2)$

$$g = 2 S/ t^2 = \text{-----} \ cm / s^2$$

Inference : The calculated value of g is a little different from actual value of g in this place of College laboratory (which we don't know exactly) due to experimental handling.

Note: Do not copy these values of the table, but take your own readings.
"Naqal Kay Leeay Uqal Chah heeay".

In this free fall experiment, plot graph between S & t. Analyze the graph by comparing it with the graph between S & t^2 .

Experiment No. 4:

Determination of value of g by free fall method using an electronic timer/ticker timer.

Apparatus:

Millisecond timer or ticker timer, free-fall apparatus for electronic timer, metal ball, cotton thread, meter rod.

Theoretical Base:

In this case of free fall apparatus, we have

Initial velocity = $v_i = 0$, distance = S

time of free fall = t , $a = g = ?$

Using the equation

$$S = v_i t + \frac{1}{2} a t^2 = 0 \times t + \frac{1}{2} g t^2 = \frac{1}{2} g t^2$$

$$\text{or} \quad g = 2S / t^2$$

Procedure:

1) *Arrange the apparatus as shown in the figure.*
2) *Check the timer and other connections.*
3) *Hold the metal ball with a fine cotton thread in such a way that it completes the electric circuit between metal contact plates on the start switch.*
4) *Measure the height from the bottom of the ball down to the trapdoor.*
5) *Adjust the ticker timer tape (or the timer) for start reading.*
6) *Release the metal ball.*
7) *Note the time of free fall from the timer.*
8) *Repeat the experiment for 5 different values of height h.*
9) *Complete all the columns of the table.*
10) *Calculate mean 'g' , and plot graph between S and t^2 .*
11) *Find the value of 'g' from the graph.*

Precautions:

1. All the connections/contacts should be checked before start.
2. Reset the clock before releasing the ball.
3. Each time take difference of at least 5 cm in height.

Viva Voce:

Q.1 *Why is this method better than free fall method?*

Ans. Here we take time from electronic arrangement, instead mechanical way.

Q.2 *Is the value of 'g' constant?*

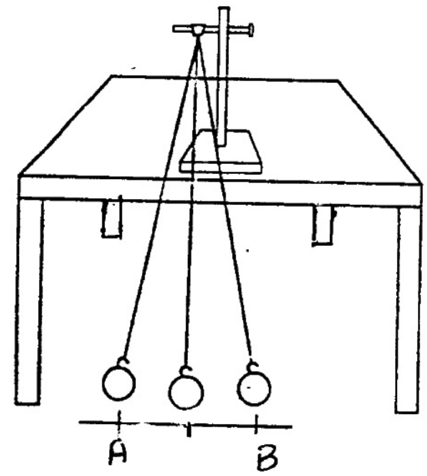
Ans. '*g*' is constant at a given place but varies from place to place.

Q.3 What is the difference between 'g' and 'G'?

Ans. 'g' is acceleration due to gravity, and 'G' is gravitational constant.

Date…………

Expt: Simple Pendulum relations.



Observations and Calculations:

i) T is independent of amplitude,
for *l* and *m* constants.
Length of the simple pendulum = ----- cm
Mass of the pendulum = *m*

No. of obs.	Amplitude *x*	Time for 20 vibrations			Time period T = t / 20
		1	2	Mean t	
	cm	s	s	s	s
1	*6*	*36.9*	*37.0*	*36.95*	*1.85*
2					
3					

Inference: Since time period remains constant, it is independent of amplitude.

ii) T is independent of mass, for *l* and *x* constants.
Length of the pendulum = ----- cm
The amplitude = ----- cm

No. of obs.	Mass of the bob *m*	Time for 20 vibrations			Time period T = t / 20
		1	2	Mean t	
	g	s	s	s	s
1	*75*	*37.0*	*37.1*	*37.05*	*1.85*
2					
3					

Inference: Since time period remains constant, it is independent of mass.

iii) $T \propto \sqrt{l}$, for *m* and *x* constant.
The radius of the bob = ----- cm

No. of obs.	Length of string including hook l_1	Total length $l = l + r$	Time for 20 vibrations			Time period T = t / 20	$T / \sqrt{l}$
			1	2	Mean t		
	cm	cm	s	s	s	s	s / √cm
1	*99.2*	*100*	*40*	*41*	*40.5*	*2.025*	*0.203*
2							
3							

Inference: Since $T / \sqrt{l}$ is constant, $T \propto \sqrt{l}$.

The Laboratory equipments are your scientific toys to play with.

1. Find height of room (or a tower) by measuring T.
2. Find time period for different amplitudes for very long 'L'.

Experiment No. 5:

Verification of following relations of the simple pendulum:

i) Time period is independent of the amplitude.

ii) Time period is independent of its mass or density of the bob.

iii) Time period is directly proportional to the square root of its length.

Apparatus:

Three bobs of different sizes and masses, stopwatch, thread, split cork, iron stand, Vernier calipers.

Theoretical Base:

In the textbook we have calculated time period of simple pendulum as,

$$T = 2\pi \sqrt{l/g}$$

Squaring the above equation, we get

$$T^2 = 4\pi^2 (l/g) \quad \text{or} \quad g = 4\pi^2 (l/T^2)$$

Procedure:

1) *Measure diameter of the bob with Vernier caliper and calculate its diameter.*
2) *Take thread about 125 cm long. Attach one end of it to the bob and the other end through split cork with the clamp of iron stand.*
3) *Below the bob, mark line parallel to the table which should be 5 cm on either of the mean position.*
4) *Adjust apparatus so that position of bob should be minimum from the floor.*
5) *Measure the length of the thread including the hook.*
6) *Take time for 20 vibrations with a stopwatch twice.*
7) *Repeat four times more by shortening length of thread by 10 cm each time.*
8) *Complete all columns of the table (iii) and hence the inference.*
9) *Mark three points on the horizontal line at distances 3, 4 and 5 cm on either side of the mean position. Vibrate the bob for these different amplitudes.*
10) *Complete table (i) and hence the inference.*
11) *Take three bobs of different masses & complete table (ii) with inference.*

Precautions:

1. The thread should be held tight without slipping.
2. The bob should not spin.
3. The length of pendulum should be 70 cm to 120 cm.

Viva Voce:

Q.1 *What is law of isochronism?*

Ans. For a pendulum when time period is independent of amplitude.

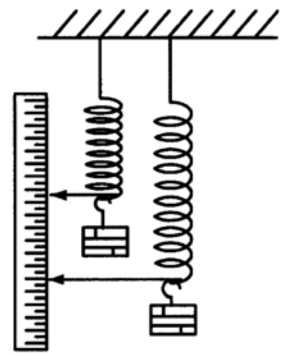
Q.2 *If earth stops rotating, will the T of a pendulum be effected?*

Ans. Yes, its time period will decrease.

Date…………

Exp: 'g' by mass-spring system.

Experimental arrangement:



Observations and Calculations:

Initial position of the pointer = ----- cm

No. of obs.	Mass suspended m	Extension	Time for 20 vibrations			Time Period	T^2	$g = \frac{4\pi^2 x}{T^2}$
		x	1	2	Mean t	T = t/20		
	g	cm	s	s	s	s	s	cm/s^2
1	100	2.35	6.1	6.2	6.15	0.3075	0.095	975.57
2								
3								

Mean 'g' = ----- cm/s^2

Actual value = 980 cm/s^2

$$\text{Percentage error} = \frac{\text{Actual value} - \text{Calculated value}}{\text{Actual value}} \times 100$$

$$= \frac{980 - 968.38}{980} \times 100 = 1.2\ \%$$

Note: The values in the table are not quite correct, certainly the student will take better than these values which are written just for guide line.

Verify oscillating mass spring system for horizontal case. Attach a body of mass 'm'. Find 'a' by oscillating mass spring system horizontally. $a = (4\pi^2 / T^2)\, x$

[$F = ma = kx \Rightarrow a = (k/m)x$ & $T = 2\pi\sqrt{m/k}$ or $k/m = 4\pi^2/T^2$]

Experiment No. 6:

To find the acceleration due to gravity by oscillating mass spring system.

Apparatus:

Helical spring apparatus, slotted weights with hanger.

Theoretical Base:

Consider a mass less spring of force constant ‘k’ in a uniform gravitational field.

We have: $F = k\,x$ & $F = mg \Rightarrow k\,x = mg$

or $m/k = x/g$ …..(1)

The time period for mass spring system is given as;

$T = 2\pi \sqrt{m/k}$ …..(2)

From equations (1) and (2) we get

$$T = 2\pi \sqrt{\frac{x}{g}} \quad \text{or} \quad g = \frac{4\pi^2}{T^2}\,x$$

Procedure:

1) *Arrange the helical spring apparatus.*
2) *Attach hanger with the spring and check its free movements.*
3) *Note initial position. Then add weights turn by turn and see the readings.*
4) *Fill the table for extensions by taking the difference between final reading and initial reading.*
5) *Take time for 20 vibrations twice.*
6) *Repeat twice and complete all the columns of the table.*

Precautions:

1. Increase the load in regular steps.
2. Pointer should not touch the scale.
3. The spring should move freely.

Viva Voce:

Q.1 *What is meant by for constant of a spring?*

Ans. Its equal to the ratio of force exerted on a spring to extension produced.

Q.2 *Define Hooke’s Law.*

Ans. The applied force is directly proportional to the elongation produced within the elastic limits.

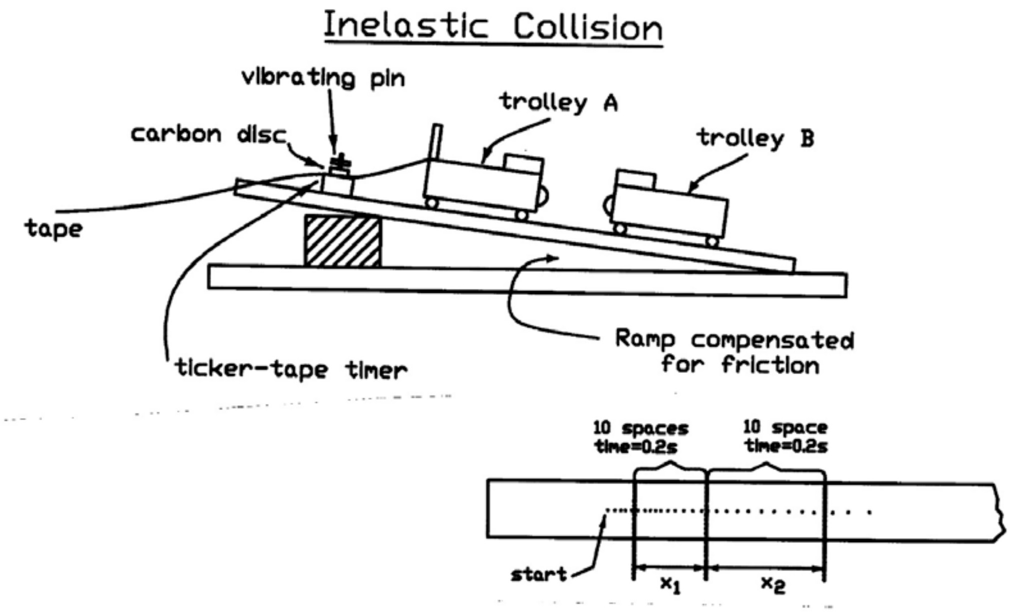
Q.3 *What is elastic limit?*

Ans. The limit beyond which the body do not obey Hooke’s Law.

Date…………

Expt: In-elastic collision.

Experiment arrangement:



Observations and Calculations:

Frequency of the ticker timer , f = 50 dots/sec
Time interval of two consecutive dots = 1/50 = 0.02 sec
Mass of the trolley A , m_1 = 223 gm
Mass of the trolley B, m_2 = 221 gm

No. of obs.	Before collision				After collision				Difference between momenta
	distance	time	Velocity	Momentum	distance	time	Velocity	Momentum	
	x_1	t_1	$x_1 / t_1 = v_1$	$(m_1 v_1)$	x_2	t_2	$x_2 / t_2 = v_2$	$(m_1 + m_2)v_2$	
	cm	sec	cm/sec	gm-cm/sec	cm	sec	cm/sec	gm-cm/sec	gm-cm/s
1	*45*	*1.5*	*30*	*6690*	*15.2*	*0.98*	*15.5*	*6886.53*	*196.5*
2	*38*	*1.36*	*27.94*	*6230.88*	*10.3*	*0..74*	*13.92*	*6180.01*	*50.88*

Average difference = 123.69 gm-cm/sec

Inference: The difference of momenta is due to frictional forces.

The values in the table are typical values, your values will not be exactly same.

1. Verify the law with two table tennis balls for elastic collision.
2. Repeat the experiment on the inclined plane after coating glue powerful enough to make them instantly stick together on contact. Analyze elastic and inelastic collisions.

Experiment No. 7(a):

To study the laws of conservation of momentum by colliding trolleys and ticker timer for inelastic collisions.

Apparatus:

Runway, two trolleys, ticker timer, ticker tape, metre rod.

Using a Ticker Timer:

A ticker timer is connected to an A.C. mains having frequency 50 cycles/sec, which makes 50 ticks every second. A vibrating metal strip strikes a strip of paper tape through a carbon paper disc and so prints a dot on the tape 50 times a second. Time interval between two dots is 1/50 seconds or 0.02 sec, as shown in the figure.

Procedure:

1) *Take the track (runway) with some slope to compensate friction.*
2) *Fit a pin to one trolley and a cork to the second trolley of equal mass.*
3) *Attach two end of ticker tape with first trolley and the ticker timer.*
4) *Place trolley B exactly opposite to trolley A at the middle of the track.*
5) *Give trolley A , a sharp push to run down the slope.*
6) *On colliding with trolley B, the pin is embedded in the cork and both move together.*
7) *From the tape find velocities of the trolleys before and after the collision.*
8) *Repeat the experiment twice and complete all columns of the table.*

Precautions:

1. Use friction compensated track & negligible friction trolley wheels.
2. The trolleys should stick together after collision.
3. Sharp and instant push should be given to trolley A.

Viva Voce:

Q.1 *What is momentum?*
Ans. It is the product and mass and the velocity of a body.

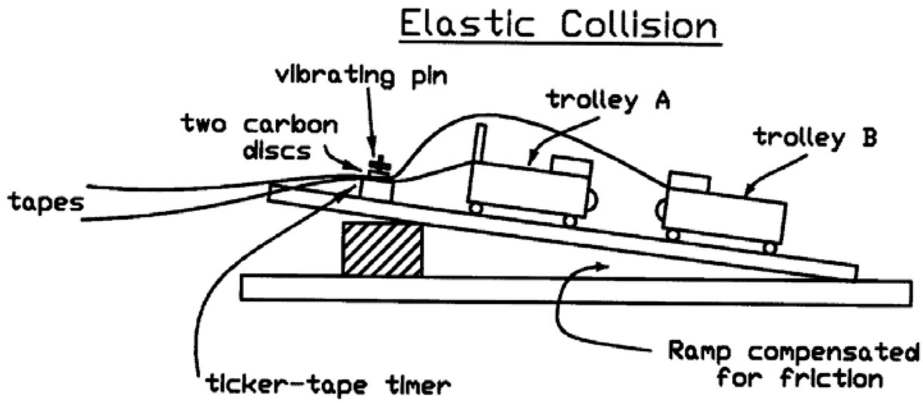
Q.2 *What is an inelastic collision?*
Ans. The collision in which total momentum is conserved but energy do not conserve before and after the collision.

Q.3 *What is the significance of momentum?*
Ans. Physically it gives the quantity of motion possessed by a body. It depends upon mass and velocity of the body.

Date…………

Expt: Elastic collision.

Experimental arrangement:



Observations and Calculations:

Frequency of the ticker timer , f = 50 dots/sec

Time interval of two consecutive dots = 1/50 = 0.02 sec

Mass of the trolley A , m_1 = 220 gm

Mass of the trolley B, m_2 = 225 gm

No. of obs.	Distance	Time	Velocity	Momentum
	x	t	*x* / t = v	m · v
	cm	sec	cm/sec	gm-cm/sec
	Trolley A before collision			
1	*31.4*	*1.6*	*19.6*	*4317*
2	*28.5*	*1.14*	*25.0*	*5500*
Trolley A after collision				
1	*-2.8*	*1.1*	*-2.5*	*-560*
2	*-3.1*	*1.47*	*2.11*	*-463.94*
Trolley B after collision				
1	*17.5*	*0.86*	*20.3*	*4567.5*
2	*20.3*	*0.91*	*22.31*	*5019.23*

1st attempt:

Total momentum before collision = 4317 + 0 = 4317 gm-cm/sec

Total momentum after collision = -560 + 4567.5 = 4007.5 gm-cm/sec

Difference = 309.5 gm-cm/sec

2nd attempt:

Total momentum before collision = 5500.0 + 0 = 5500.0 gm-cm/sec

Total momentum after collision = -463.94 + 5019.23 = 4555.29 gm-cm/sec

Difference = 944.71 gm-cm/sec

Inference: The difference of momenta is due to frictional forces.

A person rarely succeeds at anything unless he has fun doing it.

Test this collision experiment by sending two trolleys towards each other with equal speeds along a horizontal runway.

Experiment No. 7(b):

To study the laws of conservation of momentum by colliding trolleys and ticker timer for elastic collisions.

Apparatus:

Runway, two trolleys, ticker timer, ticker tape, metre rod.

Theoretical Base:

According to the law of conservation of momentum;

Total momentum before collision = total momentum after collision

or $m_1 v_i + m_2 v_i = m_1 v_f + m_2 v_f$

or $0 = m_1 (-x_1 /t) + m_2 (x_2 /t)$

or $- m_1 (x_1 /t) + m_2 (x_2 /t) = 0$

Procedure:

1) Take the track (runway) with some slope to compensate friction.

2) Fix a metallic nose instead cork to one trolley and a tab to the second trolley of equal mass.

3) Pass the both tapes through the same ticker timer. Use two carbon discs to pass the two tapes.

4) Place trolley B exactly opposite to trolley A at the middle of the track.

5) Start the ticker timer and push trolley A gently to collide elastically with trolley B.

6) From the tapes find the velocity of each trolley before and after the collision.

7) Repeat the experiment and complete all columns of the table.

Precautions:

1. Use fresh carbon discs in the timer ticker.
2. Move first trolley gently to avoid inelastic collision.
4. Use small lengths of the tapes.

Viva Voce:

Q.1 *What is elastic collision?*

Ans. Collision in which laws of conservation of energy and momentum hold.

Q.2 *Why a slope is given to the track?*

Ans. This slope supply necessary force to compensate the frictional forces.

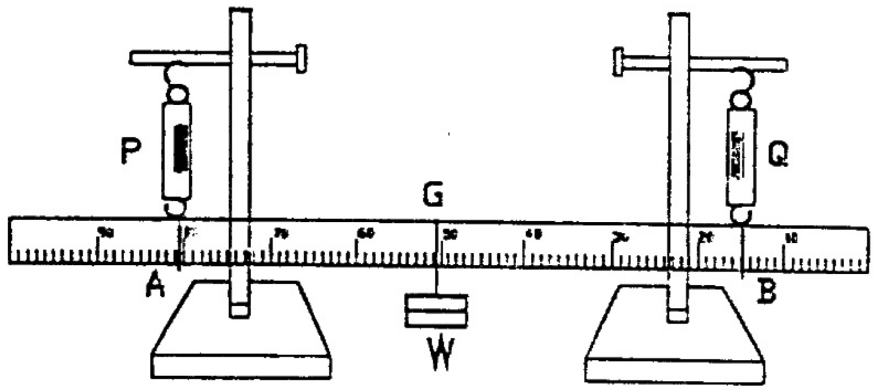
Q.3 *In this experiment, why first trolley is pushed gently?*

Ans. Is done to make elastic collision. If we push violently, it may move the second trolley and the collision may be inelastic.

Date…………

Expt: Condition of Eq. with suspended metre rod.

Experimental arrangement:



Observations and Calculations:

Position of center of gravity of meter rod = G = ----- cm

Weight of the meter rod = *w* = ----- g-wt

Axis of rotation = One end of the meter rod = C = 0.00 cm

No. of obs.	Forces			Moment arm			Torques about G			$\Sigma\tau = \tau_1 + \tau_2 + \tau_3$
							Counter Clockwise τ_1=P x AG	Counter clockwise τ_2=Q x BG	Clockwise τ_3=F x CG	
	P	Q	F = W+w	AG	BG	CG				
	g-wt	g-wt	g-wt	cm	cm	cm	g-wt-cm	g-wt-cm	g-wt-cm	g-wt-cm
1	*30*	*30*	*20+40*	*35.2*	*66.8*	*50.1*	*30 x 35.2 =1056*	*30 x 66.8 =2004*	*60 x 50.1 =3006*	*1056+2004-3006=54*
2										
3										

Verification of 2nd condition:

Summation of all the torques is nearly equal to zero, so within the limits of experimental error, $\Sigma\tau = 0$

Put metre rod edge-wise on the wedge when you take its center of gravity.

Take a small rod of known weight. Hang it with a string. Hang one known weight on one side. Press from other side to make the rod horizontal. Apply 2nd condition of Eq. And find the pressing force.

Experiment No. 8:

Verify the second condition of equilibrium using a suspended meter rod.

Apparatus:

Two iron stands, two spring balances, weights, meter rod, wedge.

Theoretical Base:

There are two conditions of equilibrium.

The **1st condition of equilibrium** states that if a number of forces acting on a body, the sum of all the forces in x-direction is zero and the sum of all the forces in y-direction should also be equal to zero; i.e. $\Sigma F_x = 0$ & $\Sigma F_y = 0$

The **2nd condition of equilibrium** states that the sum of all the torques acting on a body is zero; i.e. $\Sigma \tau = 0$.

Procedure:

1) *Find the center of gravity G of the meter rod by using a wedge.*
2) *Hang two spring balances on iron stands and check their zero correction. Attach with them a meter rod with thread loops.*
3) *Read and note both the spring balances as weight of the meter rod.*
4) *Suspend a weight W at G with a loop on the meter rod.*
5) *Note positions and readings of the spring balances.*
6) *Repeat twice by changing the positions and weight.*
7) *Complete all columns of the first table, and complete second table with the help of first table.*

Precautions:

1. Meter rod should be placed edgewise in the thread loops.
2. Meter rod should be adjusted in horizontal position.
3. Read spring balances when the apparatus is stable.

Viva Voce:

Q.1 *What are like and unlike parallel forces?*

Ans. Like parallel forces are those forces, which act in the same, direction and their lines of action are parallel to each other.

Unlike parallel forces are those forces which act in opposite direction and their lines of action are parallel to each other.

Q.2 *Why the meter rod is balanced in edgewise position.*

Ans. So that it may act like a rigid body.

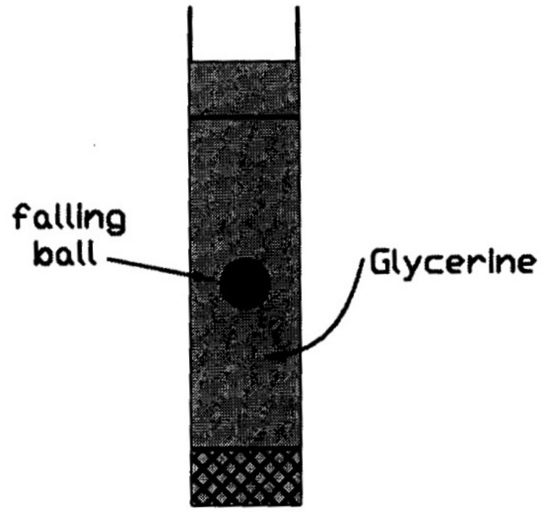
Q.3 *What are the necessary conditions for a body to be in complete equilibrium?*

Ans. It should have zero linear acceleration and zero angular acceleration.

Date…………

Expt: Coefficient of viscosity.

Experimental arrangement:



Observation and Calculations:

Diameter of the ball = i) 1.52 cm ii) 1.48 cm iii) 1.50 cm
Mean diameter = D = 1.50 cm
Radius = r = 0.75 cm = 0.0075 m
Density of glass ball = d = 1.36×10^3 kg/m^3
Density of glycerin = ρ = 1.23×10^3 kg/m^3 , (at 20^o)

No. of obs.	Distance of fall AB	Time taken t	Terminal velocity v	$\eta = \frac{2}{9} \frac{r^2 g(\rho - d)}{v}$
	m	s	m/s	N s/m^2
1	*0.14*	*0.78*	*0.18*	*0.776*
2				
3				

Mean η = ----- N s/m^2

There is no short cut to success. Just a ball has to pass through frictional force in the viscous liquid to reach the target!

1. Design a laboratory experiment to investigate how terminal velocity of the parachute depends upon the load, which it carries, and the diameter of the canopy.
2. Design an experiment to investigate how the depth of penetration varies with the speed of the pellet or small ball.

Experiment No. 9:

To study the fall of a body through a viscous medium and hence to deduce the coefficient of viscosity of the medium.

Apparatus:

Glass tube, glycerin, glass ball or steel ball, stop watch.

Theoretical Background:

[density = mass/volume or $\rho = m/V$ or $m = \rho \times V = \rho \times (4/3)\pi r^3$; & $F = mg$]

Resultant downward force on the ball = weight of ball – upward thrust

or $F = (4/3)\pi r^3 \rho g - (4/3)\pi r^3 d g = (4/3)\pi r^3 (\rho - d) g$

from Stokes Law, we have ; $F = 6\pi\eta rv$

so $6\pi\eta rv = (4/3)\pi r^3 (\rho - d) g$ or

$$\eta = \frac{2 r^2 g (\rho - d)}{9 v}$$

Procedure:

1) *Take the glass tube of about 5 cm in diameter and 50 cm in height.*
2) *Fill the tube with glycerin.*
3) *Fix one wire band at position A and the other at B, as shown in the figure.*
4) *Take small ball (having nearly 1 cm in diameter), find its diameter with vernier calipers. And fill the lines above the table.*
5) *Wet the ball with glycerin contained in a small dish.*
6) *Take a stop watch. Drop the wetted ball gently in the tube. Start the time when the ball crosses position A and stop timing when it crosses position B.*
7) *Measure the distance AB, and time t, find the terminal velocity.*
8) *Fill all columns of the table. Repeat twice.*
9) *Calculate coefficient of viscosity from the formula.*

Precautions:

1. Wetted ball should be used for dropping to avoid formation of air bubbles.
2. Tube should be fitted with a secure bung at its lower end.
3. Handle the ball with tweezers and allowed to fall centrally down the tube.

Viva Voce:

Q.1 *Define viscosity of a fluid.*

Ans. Property of fluids by which they resist their flow due to internal friction.

Q.2 *What is coefficient of viscosity?*

Ans. Is is the constant of proportionality in the relation of frictional force F,

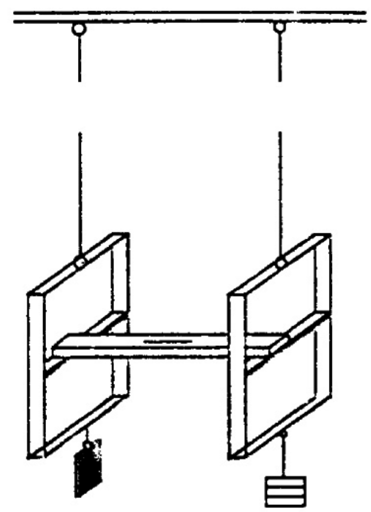
$$F = \eta A (dv/dr)$$

Q.3 *Define frictional force in case of fluids.*

Ans. The frictional force F, is proportional to the cross sectional area A, times the velocity gradient, dv/dr, (the velocity difference between two points divided by their distance apart).

Date…………

Expt: Young's Modulus for a wire.



Searle's apparatus with attachment:

Observation and Calculations:

Length of the wire = L = 398 cm

Diameter of the wire = d

i) .045 cm , ii) .055 cm,

iii) .065 cm, iv) .056 cm

Mean diameter = d = 0.055 cm

Radius = d/2 = r = .0275 cm

Area of cross-section of the wire = a = πr^2 = .00238 cm^2

No. of obs.	Loads added on the hanger	Micrometer reading			Elongation for 1 kg l
		Load increasing	Load decreasing	Mean	
	Kg	mm	mm	mm	mm
1	*0*	*1.21*	*1.22*	*1.215*	—
2	*1*	*2.11*	*2.15*	*2.13*	*0.915*
3	*2*	*2.88*	*2.90*	*2.89*	*0.76*
4	*3*	*3.71*	*3.78*	*3.745*	*0.855*
5	*4*	*4.49*	*4.49*	*4.49*	*0.75*

Mean elongation = l = 0.82 mm

= 0.082 cm

Force = M*g* = 1 x 1000 x 980 dynes

Young's modulus = Y = MgL / al = $\frac{980000 \times 398}{0.00238 \times .082}$ = 23×10^{11} dynes / cm

Actual value = 19×10^{11} dynes/cm

Percentage error = $\frac{\text{Actual value} - \text{Calculated value}}{\text{Actual value}} \times 100$

$= \frac{19 \times 10^{11} - 23 \times 10^{11}}{19 \times 10^{11}} \times 100 = 21\ \%$

Note: Its not a perfect result as 2-3 % error is allowed.

Select inflated big plastic ball. Make arrangement so that small weight can sit for a while on the ball. Find volume of the ball. Put some known weights on the ball. Estimate value of deformed volume. Calculate Bulk modulus.

$B = \frac{\text{stress}}{\text{Strain}} = \frac{MgV}{\Delta V} = \frac{Mg(4/3\pi R^3)}{\{4/3\pi(\Delta R^3)}$

Experiment No. 10:

To determine Young's Modulus of a wire by Searle's apparatus.

Apparatus:

Searle's apparatus, slotted weights with hangers, dead weight, screw guage, meter rod.

Theoretical Base:

We define elastic modulus , as the ratio of the stress on a body to the strain produced. And Young's modulus, Y , is the tensile or compressive stress. It is the force per unit cross sectional area divided by the fractional elongation of the sample. i.e. $Y = F/a \div l/L = F \times L / a \times l = MgL / \pi r^2 l$

Procedure:

1) *Suspend dead weight with reference wire and the hanger with experimental wire. Study to read micrometer reading.*
2) *For zero kilogram (only hanger) when bubble comes in the middle then note the reading.*
3) *Place turn by turn (all the given) 1 kg weights and note corresponding micrometer readings for load increasing and then for load decreasing.*
4) *Complete all columns of the table and the above and below line.*
5) *Calculate Young's modulus by applying the formula.*
6) *Note the actual value and from the formula calculate percentage error.*
7) *Plot a graph between load and elongation.*

Precautions:

1. The wires should be fixed tightly.
2. Load or unload the hanger gently.
3. The diameter should be measured from different places.

Sources of Error:

1. There might be kinks in the wire.
2. The wire might not be tightly griped from both ends.
4. The wire might be loaded beyond its elastic limits.

Viva Voce:

Q.1 *What is Young's modulus?*

Ans. It is the ratio of linear stress to longitudinal strain.

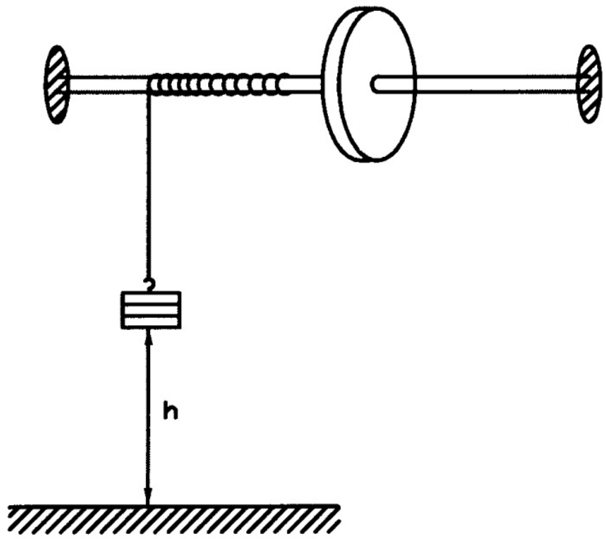
Q.2 *What do you mean by breaking stress?*

Ans. It's the load just sufficient to strain a wire beyond the elastic limit

Date:…………….

Expt: Moment of Inertia of a flywheel.

The Flywheel Apparatus:



Observations & Calculations:

Diameter of the axle = i) 3.1 cm ii) 3.0 cm iii) 2.9 cm
Mean diameter = 3.0 cm
Radius of the axle = r = 1.5 cm

No. of obs	Mass (hanger+ weights)	Height	String turns on the axle	Rotation of the wheel N			Time for N rotations t			$\omega = \frac{4\pi N}{t}$	$I = \frac{N}{N+n}\frac{m(2gh - r^2)}{\omega^2}$
	m	h	n	1	2	Mean	1	2	Mean		
	g	cm					s	s	s	rad/s	g-cm^2
1	150	121	14	19	17	18	4.3	4.1	4.2	53.82	6718.41
2											
3											

Mean I = ----- g-cm^2

The person who makes no mistakes does not usually make anything.

Take values for different weights and corresponding number of rotations. Plot graph between them. Check for straight-line curve.
[$\tau = I\alpha$ or $(r \times F) = I \times (\omega/t)$ or $F \propto \omega$, for other quantities const.]

Experiment No. 11:

To find the moment of inertia of a fly-wheel.

Apparatus:

Fly-wheel, slotted weights, thread, meter rod, stop watch., vernier calipers.

Theoretical Base:

We have; Loss of PE = gain in KE

or Loss of PE = KE_{mass} + rotational KE_{wheel} + energy used to overcome friction

or $mgh = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2 + (n/N)\frac{1}{2} I\omega^2$

or $2mgh = m(r\omega)^2 + I\omega^2(1 + n/N)$ or $2mgh - m(r\omega)^2 = I\omega^2(1 + n/N)$

or $I = \dfrac{2mgh - m(r\omega)^2}{\omega^2(1 + n/N)}$ or

$$I = \frac{N\ m}{N+n}\left(\frac{2gh}{\omega^2} - r^2\right)$$

Procedure:

1) *Check the wheel for least possible friction.*
2) *Measure the diameter of the axle from three different places.*
3) *Take the string. Make loops at its both ends for attaching one with the hanger and the other with peg of the axle.*
4) *Rotate the wheel and wrap the string on the axle.*
5) *Make a chalk mark on the wheel. Note the position of the lower surface of the weights carrying hanger.*
6) *Count the number of string turns wound on the axle.*
7) *Take a stopwatch and allow the mass to descend. As soon as the weight strike the ground, start the stopwatch. Count the number of revolutions N made by wheel before coming to rest. Take readings two times with same height and weights.*
8) *Repeat the experiment twice with different weights.*

Precautions:

1. There should be no over looping of the string on the axle.
2. Stop watch should be started just when the string is detached.
3. Measure the diameter of the axle along three mutually perpendicular axis.

Viva Voce:

Q.1 *What is moment of inertia?*

Ans. It is defined as the sum of the products of the mass and the square of the distance of different particles of the body from the axis of rotation.

Q.2 *Why flywheel has large mass in the middle?*

Ans. It is because to increase the number of rotations of the flywheel.

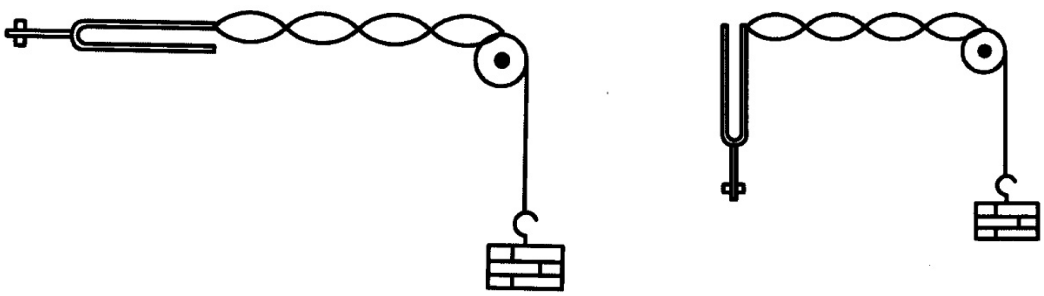
Q.3 *When the mass is allowed to fall, what happens to its potential energy?*

Ans. It partly changes into kinetic energy due to velocity gained by it and rotational energy.

Date……………

Expt: A.C. by Melde's App.

Some details of Melde's apparatus:



Observations and Calculations:

Length of the string = 500 cm

Mass of the string = ----- g

Mass per unit length = m = ----- / 500 = ----- g

No. of obs.	No. of loops	Distance between extreme nodes	Length of each loop	Total mass with hanger	Tension	$f = 1/2l\ (\sqrt{T/m})$
	p	L	l = L/p	M	T = Mg	
		cm	cm	g	dynes	hertz
1	*4*	*97.5*	*24.37*	*60*	*58860*	*104.71*
2						
3						

Mean f = ----- hertz

For transverse mode arrangement:

Frequency = f = ----- /2 = ----- hertz

Correct value of A.C. supply = 50 vib/s or hertz

Percentage error = $\frac{50 - .....}{50}$ x 100 = ... %

We never do anything well till we cease to think about the manner of doing it.

Investigate how resonant length ' l ' of a vibrating wire depends on the mass per unit length 'm' of the wire.

Experiment No. 12:

Determination of frequency of A.C. by Melde's apparatus.

Apparatus:

Melde's apparatus, string, weights with hanger, A.C. mains

Functioning Tuning Fork:

Electrical circuit is made working through the screw, when its tip comes in contact with the prong of the tuning fork. The current then passes through the electromagnet. The prongs of the tuning fork are pulled to the iron core of the electromagnet. When the prongs are pulled over, the tip of the screw breaks contact at S. This breaks the circuit and the current stops, the magnetic field dies away and the prong fly back making contact with the tip of the screw again. This makes and break of the circuit, which is repeated over and over again, keeps the tuning fork vibrating with the frequency of A.C. supply.

Procedure:

1) *Set up the electrically driven tuning fork. Tie one end of the string with the hook provided on the prong of fork and the other end with the hanger.*
2) *Start the current in the electromagnet. Put some weights (say 50 grams) in the hanger. Adjust the distance of the pulley from the fork along with weights, such that well defined loops are formed on the string.*
3) *Measure the distance L between the extreme nodes. Also the number of nodes.*
4) *Change the weight in the hanger by some grams and adjust the distance of pulley to get well defined loops again.*
5) *Repeat the process twice. Complete all the columns of the table.*
6) *Calculate the frequency for the longitudinal or transverse mode of vibrations as the case may be.*

Precautions:

1. The hanger of the weights should be tight.
2. The string should be thin and fine.
3. Weights added in the hanger should be small.

Viva Voce:

Q.1 *What is the frequency of A.C. supply?*

Ans. It is 50 cycles per second.

Q.2 *What mode of vibrations are on the string?*

Ans. These are transverse stationary waves.

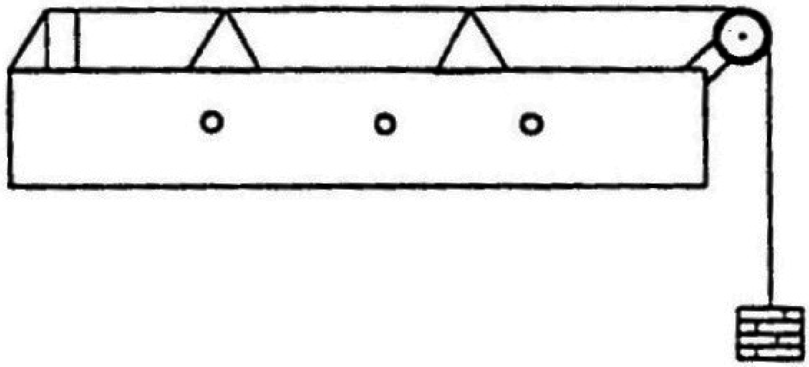
Q.3 *What are stationary waves?*

Ans. Waves apparently standing still resulting from two similar wave trains travelling in opposite directions.

Date……………

Expt: Laws of Transverse vibrations with Sonometer

Sonometer with experimental adjustments:



Observations and Calculations:

Stretching force including the hanger = ----- kg-wt

No. of obs.	Frequency	Resonant length			f x *l*
		1	2	Mean: *l*	
	hertz	m	m	m	hertz-m
1	*512*	*0.09*	*0.091*	*0.09*	*46.08*
2					
3					

Inference: *Since f x l is constant, the law of length is verified.*

Useful tip! Take the lowest frequency (say) 256 hertz first and start vibrating the string by moving one of the bridge very slowly and gently.

Measure frequency of an unknown tuning fork using sonometer.
[Find resonant length ‘ *l* ’ with known tuning fork. Find, const = fx*l*.
Determine resonant length of unknown fork keeping tension const.
find ‘f’ from; fx*l* = const]

Experiment No. 13(a):

Investigation of the law of length of stretched strings by sonometer.

Apparatus:

Sonometer, three tuning forks of different frequencies, rubber pad, slotted weights with hanger, bridges, and meter rod.

Theoretical Background:

We have in case of transverse vibrations of string;

$$f = 1/2l\,(\sqrt{T/m})$$

The factors *l*, m & T are all variables, ν will vary as they are altered.

We have **Law of length** as; $f \propto 1/l$, when m and T are constant.

Procedure:

1) *Arrange the apparatus as shown in the diagram.*
2) *Put a load of one kg or 2 kg on the hanger. Place bridges very near to each other.*
3) *Put a light paper rider on the wire between the bridges.*
4) *Take the tuning fork having the lowest frequency (say 256). Vibrate it with a rubber pad.*
5) *Gently place the vibrating tuning fork on the board between the bridges. At the same time move slowly position of one of bridge, till the paper rider moves off.*
6) *Measure the length of the wire between the bridges for two good resonating positions when the paper rider moves off.*
7) *Repeat it with two more tuning forks, and complete all the columns of the table.*

Precautions:

1. The wire should have no kinks.
2. The edge of the bridges should be sharp.
3. The paper rider should be in the middle of vibrating segment.

Viva Voce:

Q.1 *What is law of length?*

Ans. $\nu \propto 1/l$ when T and *m* are constant: That is 'the frequency of transverse vibration of a stretched string is inversely proportional to its vibrating length' under a constant stretching force.

Q.2 *Why is it called sonometer?*

Ans. As it can measure the frequency of sound.

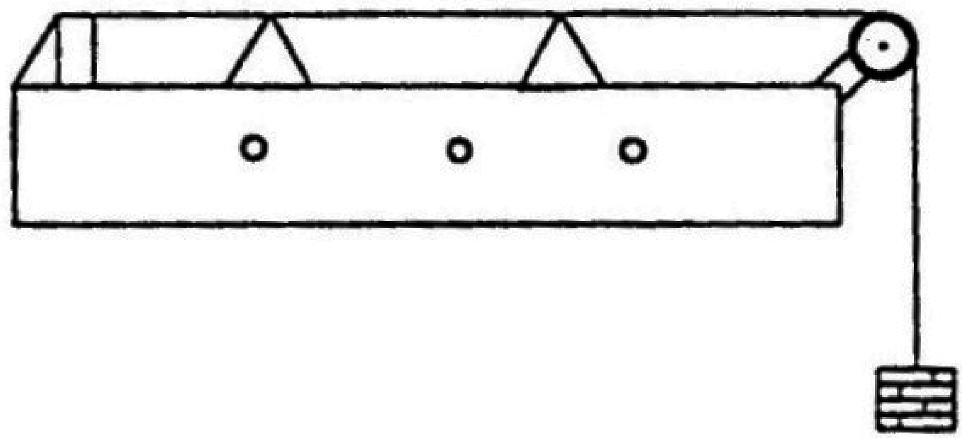
Q.3 *What is the function of holes in the sonometer?*

Ans. To make communication with the atmospheric air possible.

Date……………

Expt: Law of Tension with Sonometer

Sonometer with experimental arrangements:



Observations and Calculations:

Length of vibrating segment = ----- m

No. of obs.	Frequency	Total load			Tension	$\sqrt{T}$	$f/\sqrt{T}$
		1st	2nd	Mean	T = *mg*		
	Hertz	kg-wt	kg-wt	kg-wt	Newtons		
1	*512*	*1.5*	*1.51*	*1.5*	*14.7*	*3.83*	*133.7*
2							
3							

Inference: *Since $f/\sqrt{T}$ is constant, the law of tension is verified.*

Useful tip! *Take least frequency reading (of last experiment) with 1.5 kg load and add weights by 0.1 kg (100 grams) for higher frequency tuning forks.*

In sonometer experiment, verify law of mass by taking wires of different materials. We have $f = (1/2l) \times (\sqrt{T/m})$, for constant tension & resonating length, $f \propto 1/\sqrt{m}$ or $\sqrt{m} \times f$ = const

Experiment No. 13(b):

Investigation of the law of tension of stretched strings by sonometer.

Apparatus:

Sonometer, three tuning forks of different frequencies, rubber pad, slotted fractional & kg-weights with hanger, bridges, and meter rod.

Theoretical Background:

From the formula;

$$\nu = 1/2l\,(\sqrt{T/m})$$

We have **Law of tension** as; $\nu \propto \sqrt{T}$, when l and m are constant.

Procedure:

1) *Stretch the wire over the sonometer with a load on hanger.*
2) *Find the resonating length for the lowest frequency and note it above the line of the table.*
3) *Increase the load in steps by 0.1 kg till the same length of the wire resonates with second tuning fork of higher frequency.*
4) *Take two observations for each tuning fork, and use total three tuning forks of different frequencies.*
5) *Complete all the columns of the table.*
6) *Plot a graph between T verses* ν^2 *by taking T along X-axis. It will be a straight line graph.*

Precautions:

1. The load of the hanger must be included.
2. The wire should not be loaded beyond the breaking stress.
3. Vibrating tuning fork should be placed very softly.

Viva Voce:

Q.1 *What is law of tension?*

Ans. $\nu \propto \sqrt{T}$ when l and m are constant: That is 'the frequency of transverse vibration of a stretch strings is directly proportional to the square root of its tension for a given length'.

Q.2 *What type of vibration is executed by sonometer wire?*

Ans. It executes transverse vibrations.

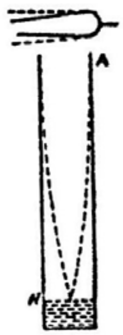
Q.3 *Why is sonometer sometimes called monochord?*

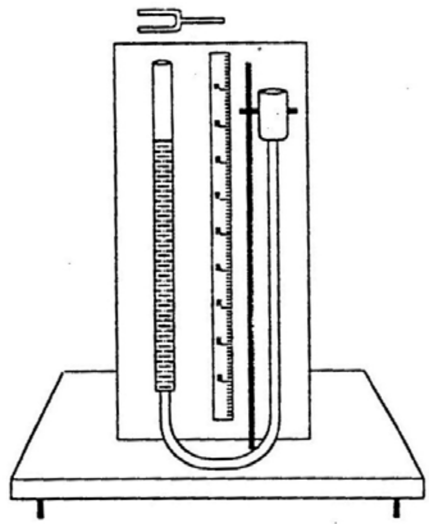
Ans. As it consists of a single wire.

Date……………

Expt: Velocity of sound by end correction.

Resonance tube apparatus with the position of tuning fork:





Observations and Calculations:

Internal diameter of the tube = i) ----- cm , ii) ----- cm , iii) ----- cm

Mean diameter = D = ----- cm

End correction = 0.3D = 0.3 x ----- = ----- cm

Room temperature = t = ----- ^oC

No. of obs.	Frequency	Resonance position			Length of resonating air column	$v_t = f\lambda$ $= f \times 4l$
	f	1	2	Mean: L	$l = L + 0.3D$	
	hertz	cm	cm	cm	cm	cm/s
1	*512*	*15.2*	*15.3*	*15.25*	*16.503*	*33798.1*
2						
3						

Mean v_t = ----- cm/s

Velocity of sound at 0 ^oC = $v_o = v_t - 61t$

or v_o = ----- – (61 x -----) = ----- cm/s

Actual value = 33200 cm/s

Percentage error = $\frac{\text{Actual value – calculated value}}{\text{Actual value}} \times 100$

= $\frac{33200 - \text{-----}}{33200} \times 100$ = ----- %

Note: *When you take second tuning fork for finding resonance position, if its frequency is higher than previous one, lower the water level. And if the frequency of second tuning fork is less, then raise the water level for finding the resonance position.*

Find the unknown frequency of a tuning fork. [Find ' l ', determine v_t from the formula, then calculate $f = v_t / 2l$]

Experiment No. 14(a):

To determine the wave length of sound in air using stationary waves and to calculate the speed of sound by one resonance position and applying end correction.

Apparatus:

Resonance tube apparatus, three tuning forks of different frequencies, rubber pad, thermometer, vernier calipers, set squares and meter rod.

Procedure:

1) *Set the apparatus in vertical and stable position.*
2) *Bring the reservoir to the upper part of the stand, so that water rises to fall in the resonance tube.*
3) *Strike a tuning fork on the rubber pad, and very slowly lower the water level in the tube by lowering the reservoir or by loosing the pinchcock.*
4) *During vibrations, when a magnified sound is heard, note that position of the water level.*
5) *Lower the water level a little and then slowly rise. Again note the clear magnified sound as its second reading.*
6) *Repeat the above with two more tuning forks.*
7) *Complete all the columns of the table and the lines above the table.*
8) *From calculated and actual values find the percentage error.*

Precautions:

1. Lower meniscus of the water level should be read.
2. The vibrating prong should not touch the edge of the tube.
3. Strike the tuning fork gently against the rubber pad.

Sources of Error:

1. The tuning fork might not be held horizontally.
2. The vibrations of the tuning fork might not be stopped before revibrating it.
3. The exact position of resonance might not be located correctly.

Viva Voce:

Q.1 *What types of waves are produced in the tube?*

Ans. Longitudinal stationary waves are produced.

Q.2 *What is the effect of temperature upon the velocity of sound?*

Ans. It increases with increase of temperature.

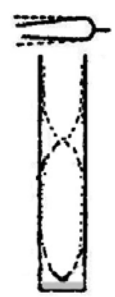
Q.3 *What is end correction?*

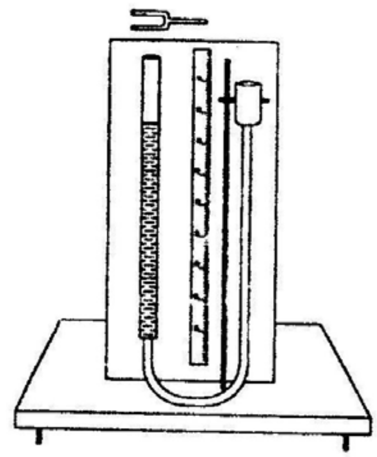
Ans. The antinode does not lie at the centre of open end but slightly above. This shift in the position of antinode is called end correction.

Date……………

Expt: Velocity of sound by two resonance positions.

Resonance tube apparatus with tuning fork position:





Observations and Calculations:

Room temperature = t = ... ^{o}C

No. of obs.	Frequency f	First position of resonance			Second position of resonance			Length $l = \lambda/2 = L_2 - L_1$	$V_t = 2fl$
		1	2	Mean : L_1	1	2	Mean : L_2		
	Hertz	cm	cm	cm	cm	cm	cm	cm	cm/s
1	*512*	*15.2*	*15.3*	*15.25*	*48.4*	*48.2*	*48.3*	*33.03*	*33825*
2									
3									

Mean v_t = ... cm/sec

Velocity of sound at 0 ^{o}C = $v_o = v_t - 61t$ =

= .... – (61x31.5) = ... cm/sec

Actual value = 33200 cm/sec

Percentage error = $\frac{33200 - ....}{33200}$ x 100 = ... %

Useful tip! Take highest frequency reading of last experiment, lower the water level two times further, then check for second resonance position. This time the sound heard will be less.

Compare frequencies of two tuning forks. [$v_t = 2fl$ & $v_t = 2\nu' l'$ or $v_t / v_t = 1 = 2\nu l/2\nu' l'$ or $f'/f = l/l'$]

Experiment No. 14(b):

To determine the wave length of sound in air using stationary waves and to calculate the speed of sound by using two resonance positions.

Apparatus:

Resonance tube apparatus, three tuning forks of different frequencies, rubber pad, thermometer, vernier calipers, set squares and meter rod.

Theoretical Background:

We have for 1st position of resonance; $l = \lambda/4$ or $l = l_1 + 0.3D$ …..(1)

For 2nd position, the length is, $l = \lambda/4 + \lambda/2 = 3\lambda/4 = l_2 + 0.3D$ ….(2)

From equations (1) & (2) we get

$$3\lambda/4 - \lambda/4 = l_2 + 0.3D - l_1 + 0.3D$$

$$\text{or} \quad \lambda = 2(l_2 - l_1)$$

so velocity of sound, v will be

$$v = \lambda f \quad \text{or} \quad \boxed{v_t = 2\nu(l_2 - l_1)}$$

Procedure:

1) *Adjust the apparatus for first resonance position with different three tuning forks.*
2) *Note the reading for First resonance position with different three tuning forks.*
3) *Lower the water level in the tube about three times the length of first resonance position.*
4) *Keeping the same vibrating tuning forks above the open end of the tube, after some lowering or rising the water level, again a magnified sound is heard. Note this resonance position.*
5) *Complete all the columns of the table and the lines above the table.*
6) *Repeat twice. From calculated and actual values find the percentage error.*

Precautions:

1. The apparatus should be made vertical.
2. During the experiment if temperature varies, take mean value.
3. The vibrations of the tuning fork should be stopped before re-vibrating it.

Viva Voce:

Q.1 *What is an echo?*

Ans. A reflected sound is called an echo.

Q.2 *What role does water play in resonance tube?*

Ans. It simply changes the length of air column.

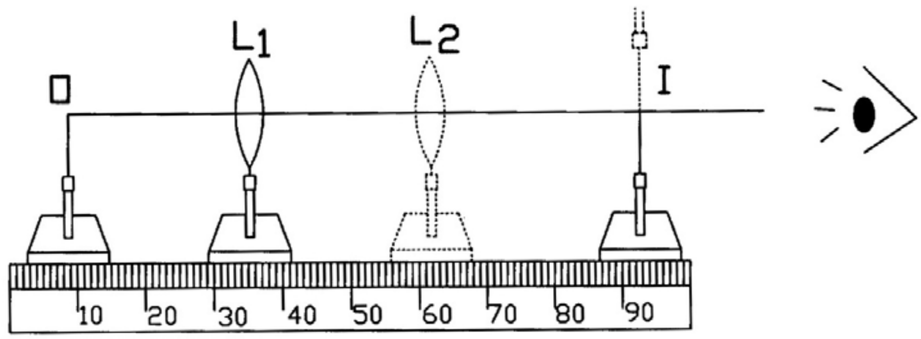
Q.3 *What is that which vibrates in the resonance tube?*

Ans. It is the air column.

Date…………

Expt: Focal length of a convex lens by displacement.

Experimental arrangements for displacement method:



Observations and Calculations:

Approximate focal length = f = ----- cm
Length of knitting needle = l_1 = ----- cm
Distance between two needles = l_2 = ----- cm
Index correction for the needles = $l_1 - l_2$ = ----- cm

<table>
<tr><th rowspan="3">No. of obs.</th><th colspan="4">Positions of</th><th rowspan="3">d = L₂ – L₁</th><th colspan="2">Distance, l (between O & I)</th><th rowspan="3">f = (l² – d²) /4l</th></tr>
<tr><th>Object needle</th><th>Image needle</th><th colspan="2">Lens</th><th>Observed</th><th>Corrected</th></tr>
<tr><th>O</th><th>I</th><th>L₁</th><th>L₂</th><th>l′</th><th>L</th></tr>
<tr><td></td><td>cm</td><td>cm</td><td>cm</td><td>cm</td><td>cm</td><td>cm</td><td>cm</td><td>cm</td></tr>
<tr><td>1</td><td>17.9</td><td>68.8</td><td>50</td><td>36.8</td><td>13.2</td><td>50.9</td><td>50.2</td><td>11.8</td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Mean f = ….. cm

We are born with two eyes but one tongue, in order that we observe twice.

Discover inverted image on retina:
Take a card and make a hole in it with a pin. Hold the card close to your eye and look at a strong light through the pinhole. Place the pin between your eye and the card so that the head of the pin covers part of the pinhole. The shadow of the pin will appear upside down. [The eye acts merely like a window, when placed an object very close to the eye].

1. Compare the difference of approximate focal length and calculated focal length for a thin convex lens and a thick convex lens.
2. Show there are two coaxial positions of a convex lens, which will give, on a fixed screen, a sharp image of a fixed object.

Experiment No. 15:

To determine the focal length of a convex lens by displacement method.

Apparatus:

Convex lens, two needles, knitting needle, three uprights, set square and meter rod.

Theoretical Background:

The formula used for finding the focal length is;

$$f = (l^2 - d^2)/4l,$$

where l is the distance between object needle and image needle,

& d is distance between the displacement of lens

Procedure:

1) *Find the approximate focal length F.*
2) *Adjust the three uprights such that the distance between the two needles is about 4F, the lens being in middle. Distance p is little greater than F.*
3) *Remove the parallax. And note the positions L_1, O and I.*
4) *Without moving O, and I move the lens towards I and again remove the parallax. Note the position L_2 .*
5) *Repeat the experiment twice by changing the distance between the needles.*
6) *Find the index correction for needles, by filling the lines above the table.*
7) *Complete all the columns of the table.*

Precautions:

1. Distance between the two needles should be greater than 4F.
2. For second observation parallax should be removed only by moving the lens.
3. For removing parallax look from a large distance to avoid strain on the eye.

Sources of Error:

1. The parallax might not be removed over the central portion of the lens.
2. The eye might be kept at distance less than 25 cm during removing parallax.
3. The needles might not be well illuminated.

Viva Voce:

Q.1 *What is optical center of the lens?*

Ans. A point inside a lens, where is no deviation to a ray.

Q.2 *Why displacement method is better than the two needle methods?*

Ans. Here only one index correction is required.

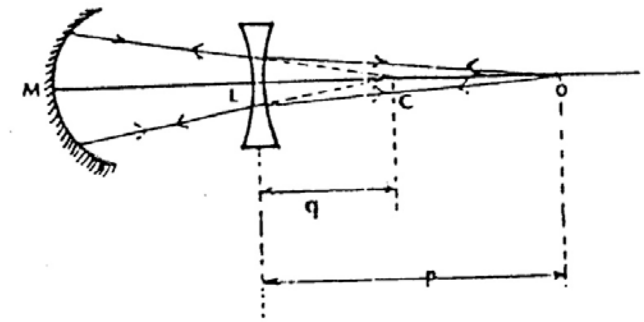
Q.3 *What is the minimum distance between object and its real image for convex lens?*

Ans. It is exactly equal to four times the focal length of the lens.

Date………..

Expt: Focal length of concave lens by concave mirror.

Experimental Illustration:



Observations and Calculations:

Approximate focal length of concave mirror = f = ----- cm
Length of knitting needle = x = ----- cm
Distance between needle and mirror = y = ----- cm
Distance between needle and lens = z = ----- cm
Index correction for concave mirror = $x - y$ = ----- cm
Index correction for concave lens = $x - z$ = ----- cm
Position of the mirror = M = ----- cm

No. of obs.	Position of			Observed		Corrected		f = $\frac{p \times q}{p+(-q)}$
	Needle at C	Lens L	Needle at O	p′ OL	q′ CL	p	Q	
	cm	cm	cm	cm	cm	cm	cm	cm
1	28.5	18.9	44.3	25.4	9.6	25.0	9.3	- 14.8
2								
3								

Mean f = - _______ cm

Archimedes set the Roman fleet on fire by means of an arrangement of mirrors and lenses.

In this focal length of convex lens experiment, take a graph paper, graphically construct the ray diagram, measure p & q and find f.

Experiment No. 16(a):

To determine the focal length of a concave lens by using a concave mirror.

Apparatus:

Concave lens, concave mirror, three uprights, meter rod, knitting needle.

Theoretical Background:

A concave lens is a diverging lens. In this lens the rays diverge after passing through it. So looking the image is difficult. We use such device, which makes the rays converging, so that we can see the image. For looking the image, we can use concave mirror or convex lens to make the rays converging.

Procedure:

1) *Find the approximate focal length of the concave mirror.*
2) *Mount the mirror and the parallax needle on the uprights. Remove the parallax between the needle and its inverted image. Now the needle will be at C.*
3) *Place the concave lens between the mirror and object needle without changing the position of mirror. Now again remove the parallax.*
4) *Note the positions of object needle, lens and mirror after removing the parallax.*
5) *Repeat twice by changing the positions of the lens.*
6) *Measure the length of knitting needle and find index corrections for the mirror and the lens by filling the lines above the table.*
7) *Taking 'p' positive and 'q' negative, apply formula and calculate the focal length.*

Precautions:

1. The concave mirror should be of small focal length.
2. The mirror position should be kept same.
3. Parallax should be removed carefully.

Sources of Error:

1. The position of the mirror might be changed during the experiment.
2. Parallax might not be removed tip to tip.
3. Principal axis of the mirror might not be parallel to the optical surface.

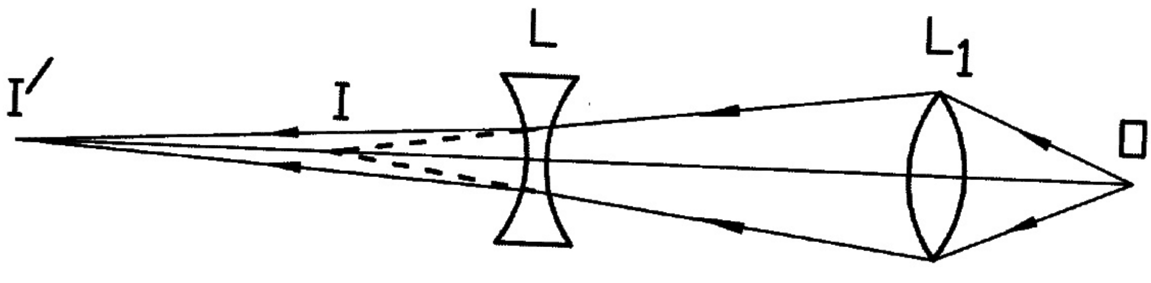
Viva Voce:

Q.1 *What is the nature of image formed by concave lens?*
Ans. It is virtual, erect and diminished in size.
Q.2 *How you define the power of a lens?*
Ans. It is the reciprocal of the focal length of a lens.
Q.3 *Why should the focal length of a concave mirror be short?*
Ans. To keep the combination of lens and mirror convergent over certain range.

Date………..

Expt: Focal length of concave lens by convex lens.

Experimental Illustration:



Observations and Calculations:

Approximate focal length of convex lens = f = ----- cm
Length of knitting needle = x = ----- cm
Distance between concave lens and image needle = y = ----- cm
Index correction for p = $x - y$ = ----- cm
Index correction for q = $x - z$ = ----- cm

No. of obs.	Position of					Observed		Corrected		$f = \frac{p \times -q}{p+(-q)}$
	Needle at	Convex lens	Concave lens	Needle at		p'	q'	p	q	
	O	L_1	L	I	I′	LI	LI′			
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
1	28.5	18.9	34.7	44.3	60.1	9.6	25.4	9.3	25.0	- 14.8
2										
3										

Mean f = - ______ cm

Take your own readings. Borrowed plumes are weak for flying.

1. Find focal length of a concave lens using a prism.
2. Take luminous object. Put screen instead of direct looking for image. Calculate focal length of concave lens.

Experiment No. 16(b):

To determine the focal length of a concave lens by using a convex lens.

Apparatus:

Concave lens, convex lens, three uprights, meter rod, knitting needle.

Procedure:

1) *Find the approximate focal length of the convex lens.*
2) *Place the object needle O beyond the focus of the convex lens.*
3) *On the other side of the lens, place the image needle beyond 2F.*
4) *Remove the parallax between the object needle and image needle. . Note the position I of the image needle.*
5) *Place concave lens between lens and image needle delicately.*
6) *Again remove the parallax to locate the new position I′ and note it.*
8) *Find index correction for the image and object distances by filling the lines above the table. Fill all the columns of the table.*
9) *Calculate the mean focal length from the formula.*

Precautions:

1. Positions of O and I should remain unchanged when position of L is adjusted.
2. A concave lens of shorter focal length is preferred.
3. The aperture of the concave lens should be large.

Sources of Error:

1. The aperture of the concave lens might not be somewhat large.
2. The position of the uprights might not be read up to in millimeters.
3. The convex lens and the concave lens might not be formed a suitable combination to give undistorted inverted image.

Viva Voce:

Q.1 *What is the difference between convex lens and concave lens?*

Ans. Convex lens is thicker in the center and thinner at the edges, but concave lens is thinner in the center and thicker at the edges.

Q.2 *Why is parallax not removed over the whole aperture of the lens?*

Ans. The parallax is not removed over the whole aperture of the lens because of spherical aberration it is not possible.

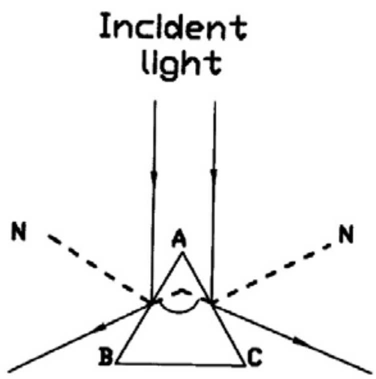
Q.3 *What type of image is formed by convex lens and concave lens?*

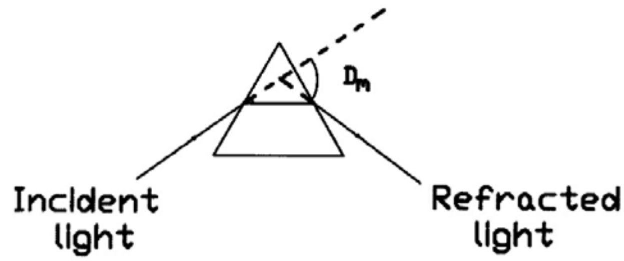
Ans. Convex lens forms a real image except object lies within its focal length, and concave lens always forms a virtual image.

Date………..

Expt: Refractive index of the material by spectrometer.

Some experimental details:





Observations and Calculations:

Least count of the spectrometer = ____ cm

Table for angle of the prism A:

No. of obs.	Telescope reading		Difference = 2A	Angle A
	Left	Right		
1	*6°16′00″*	*66°15′30″*	*59°59′30″*	*29°59′45″*
2				
3				

Mean angle of the prism A = 60° 00′ 05″ = 60°

Table for the angle of Minimum Deviation, D_m :

No. of obs.	Min. Deviation reading	Direct reading	Difference = D_m
1	*70°11′30″*	*30°33′00″*	*39°38′30″*
2			
3			

Mean D_m = ______
= _______

Index of refraction = $\frac{\sin (A + D_m) / 2}{\sin A /2} = \frac{\sin(60 + ...) /2}{\sin (60 / 2)}$
= ......

Your eyes open more in the dark than in the light!

Mount a metal stick nearly 5 m away. Put steam-producing water in between your eyes and the object. Look that twinkling object, looking like stars at night. It is due to refraction of light from heated layer of air.

Experiment No. 17(a):

To find the refractive index of the material of a prism using spectrometer.

Apparatus:

Spectrometer, glass prism and sodium light arrangement.

Procedure:

1) *Take the spectrometer in open window, focus the telescope for infinity, also focus the cross wires.*
2) *Place the spectrometer in front of sodium light. Adjust collimator.*
3) *Make the collimator and telescope in line. Adjust slit image.*
4) *Place the prism on the turntable so that edge 'A' towards collimator and light falls on both of the faces of the prism.*
5) *Move the telescope away. Adjust the image with naked eye so that you can look for clear and aligned image on both sides.*
6) *Turn the telescope. See and note the readings from both sides.*
7) *For angle of minimum deviation, place the prism on the table with its edge towards left so that light falls on its one of the face AB. Look for emergent rays through face AC.*
8) *Rotate the table so as the image moves in one direction, stops just as it appears to turn back. Note this reading.*
9) *Remove the prism. Bring the telescope in line with collimator. Note direct reading.*
10) *Complete the tables and calculate index of refraction.*

Precautions:

1. The slit should be narrow and fine.
2. Firstly the telescope should be set for infinity.
3. Do not touch the sides of the prism; instead handle it from the top or bottom of the prism.

Viva Voce:

Q.1 *Upon which factors the critical angle depends?*

Ans. It depends upon; i) the nature of the material of prism, and ii) nature of the other medium.

Q.2 *What is angle of deviation and minimum deviation?*

Ans. Angle of deviation is the angle between incident ray and emergent ray. When light passes symmetrically through the prism, its value is minimum.

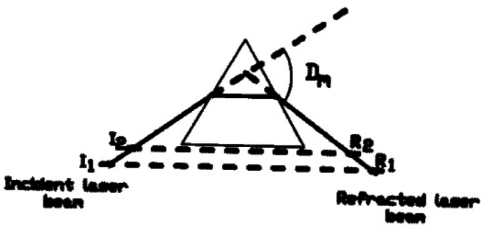
Q.3 *What is deviation of light?*

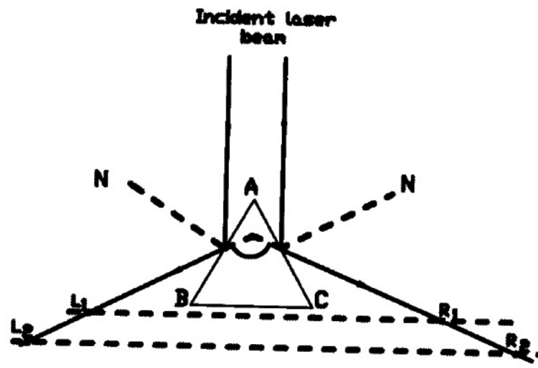
Ans. When light enters from one medium into another medium of different density, it changes its path, which is called deviation.

Date………..

Expt: Refractive index of the material by laser.

Some experimental details:





Observations and Calculations:

Table for angle of the prism A:

Laser pointer at				From geometry of the figure	Angle of prism
Left side		Right side			
L_1	L_2	R_1	R_2	2A	A
cm	cm	cm	cm	Degrees	Degrees
22.5	*27.3*	*49.5*	*61.3*	*30.01*	*60.0*

A = 60.0°

Table for the angle of Minimum Deviation, D_m :

Laser pointer at				From geometry of the figure
Incident light		Refracted light		
I_1	I_2	R_1	R_2	D_m
cm	cm	cm	cm	Degrees
42.4	*37.3*	*77.1*	*65.2*	*39.5*

$D_m = 39.5°$

$$\text{Index of refraction} = \frac{\sin (A + D_m) / 2}{\sin A / 2} = \frac{\sin(60 + 39.5) / 2}{\sin (60 / 2)} = 1.52$$

Thoughtful question: *How rainbow is formed in the sky after raining?*

With a prism take different values of angle of incidence and angle of deviation. Plot a graph between them. Find angle of minimum deviation from the graph.

Experiment No. 17(b):

To find the refractive index of the material of a prism using a laser.

Apparatus:

Glass prism, laser source, half metre rod, protector.

Theoretical Base:

When a ray of light passes from rarer (air) medium to denser (glass prism) medium, it bends towards the normal. This is called refraction.

According to Snell's Law; refractive index = n = $\frac{\sin (A + D_m) / 2}{\sin A /2}$

where A = Angle of prism, D_m = Angle of minimum deviation

Procedure:

1) *Take the laser source and adjust its pointer.*
2) *Place the prism on the turntable so that edge 'A' towards the laser light such that the laser light falls on both of the faces of the prism.*
3) *Adjust the ray both sides, as shown in the figure.*
4) *Place the screen at the position L_1 R_1 and look for the refracted light spots. Note their positions.*
5) *Now place the screen at the position L_2 R_2 and look for the refracted light spots. Note their positions.*
6) *For angle of minimum deviation, place the prism on the table with its edge towards left so that laser light falls on its one of the face AB. Look for emergent rays through face AC.*
8) *Rotate table so as the ray moves in one direction, stops just as it appears to turn back. Note readings by placing a screen at the two positions I_1 R_1 and I_2 R_2 .*
9) *Remove the prism. Do the geometrical work as in the figure.*
10) *Complete the table and calculate index of refraction.*

Precautions:

1. Do not look directly on the laser light.
2. Use sharp pointed laser light.
3. Clean sides of the prism before using it.

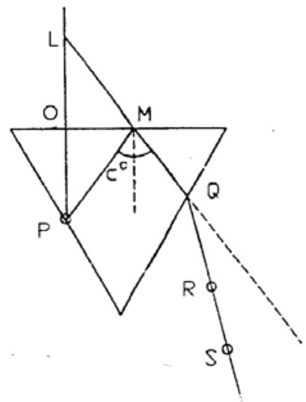
Viva Voce:

Q.1 *What acronym LASER stands for?*
Ans. Light Amplification by the Stimulated Emission of Radiation.
Q.2 *In lab why laser is preferable to sodium light?*
Ans. We can perform the experiment without having a dark room.
Q.3 *Do all holograms need laser light to give an image?*
Ans. No. Some holograms work using reflected daylight.

Date…………

Expt: Critical angle for glass using prism.

Geometrical work for finding critical angle with the prism:



Observations and Calculations:

No. of obs.	∠ PMQ	Critical Angle = ½ ∠ PMQ
	degrees	degrees
1	81	40.5
2		
3		

Mean critical angle = C = _____

Refractive index of glass = n = 1/sinC = 1/ sinC = _____

Science knows only one commandment—contribute to Science.

1. Determine the refractive index of glass slab using a traveling microscope.
2. Make such arrangements, to calculate refractive index of water.

Experiment No. 18:

To find the refractive index of the material of a prism by critical angle method.

Apparatus:

Prism, pins, drawing board, paper sheet, set square, Dee, half-meter rod.

Procedure:

1) *Fix a sheet of paper on a drawing board. Place a prism with its base BC away. Draw its boundary ABC.*
2) *Remove the prism. Fix pin P in the middle of line AB.*
3) *Replace the prism on its boundary, such that the pin P just touches the face AB.*
4) *Look through the face AC with the eyes near C. Move the eyes towards A. fix pins at R and S in line with the image of P when it becomes just faint.*
5) *Remove the prism and the pins. Encircle the pin's points.*
6) *Draw a straight line through R and S up to Q.*
7) *From P draw PO perpendicular to BC and produce it to L to make PO = OL. Join L to Q, cutting BC at M.*
8) *Join PM and mark the path of the rays.*
9) *Measure the angle PMQ. Half of ∠ PMQ is the critical angle.*
10) *Calculate refractive index from the formula.*

Precautions:

1. The prism with clear faces should be used.
2. The pins should be vertical and well apart.
3. The pin P should touch the face of the prism.

Sources of Error:

1. The point where image of the pin disappears might not be located exactly during fixing of the pins.
2. Error due to thickness of the pins.
3. Error might be due to not fine geometrical work.

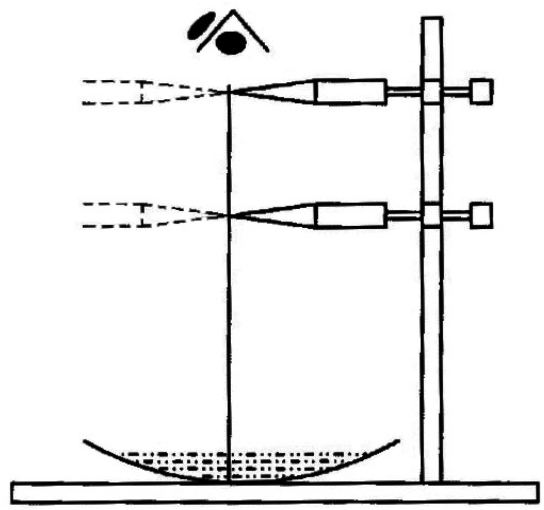
Viva Voce:

Q.1 *Why the pin P should touch the face of the prism?*
Ans. So that it may serve as an object lying in the glass.
Q.2 *Why OL is cut equal to OP?*
Ans. In this case, the image is at the same distance behind base BC as the object P is in front of it.
Q.3 *Does critical angle differ with colour of light?*
Ans. Yes. It is greater for red light and smaller for violet light.

Date…………

Expt: Refractive index of liquid by concave mirror.

Some experimental details:



Observations and Calculations:

Approximate focal length of the concave mirror = f = ----- cm

No. of obs.	Height of the needle from the surface of mirror after removing the parallax		$n = \frac{h_1}{h_2}$
	without liquid, h_1	with liquid, h_2	
	cm	cm	
1	25.4	19.1	1.329
2			
3			

Mean refractive index of the liquid (water) = n = ...

Note: Mirror image is not up side down but it is left side right!

Differentiate between the images seen;
i) in the mirror, ii) on a screen through a lens,
iii) on a screen through a slide projector, iv) on a TV screen.
Try to shake hand with each of that image (if that is a man)!

Experiment No. 19:

To find the refractive index of a liquid, using a concave mirror.

Apparatus:

Concave mirror, tripod stand, needles, stand, plumb line & meter rod.

Theoretical Background:

In case of concave mirror, there is no parallax between the object and the image seen, as the rays strike the mirror normally and retraces its path back to form an inverted image just at the center of curvature.
When some liquid is put on the mirror, the ray no longer strikes normally due to refraction inside the liquid and no parallax position is disturbed. So we have to remove the parallax.
Formula is; refractive index of a liquid = n = real depth/ apparent depth

Procedure:

1) *Find the approximate focal length of the concave mirror.*
2) *Adjust the apparatus as shown in the figure.*
3) *Remove parallax between the needle and its image in such away that tip of the needle lies at the centre of curvature of the mirror.*
4) *Pour sufficient quantity of the liquid (water).*
5) *Measure vertical height from above the liquid surface to the tip of the needle with a plumb line.*
6) *Again remove the parallax, as the image seen through the liquid.*
7) *Measure the height as before.*
8) *Repeat twice. Calculate refractive index of the liquid.*

Precautions:

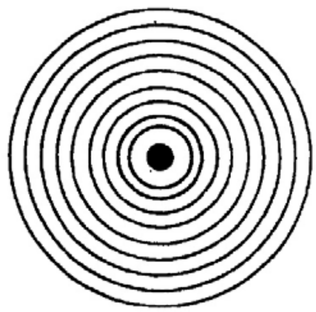
1. Mirror should be of large focal length.
2. The surface of the mirror should be cleansed with spirit.
3. To avoid distortion and high curvature, enough liquid should be used.

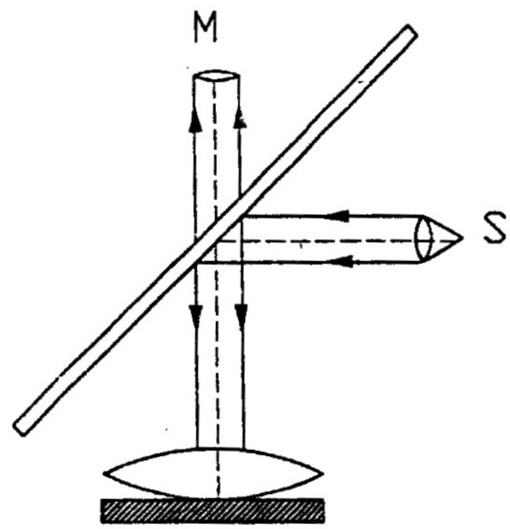
Viva Voce:

Q.1 *Why we use concave mirror of large radius of curvature?*
Ans. To adjust the approximation used in the formula.
Q.2 *Why we use $n = CA/C'A$, instead the correct relation, $n = CP/C'P$?*
Ans. With large radius of curvature and small liquid depth, the ratio is nearly same; i.e. $CA/C'A = CP/C'P$
Q.3 *What is parallax method?*
Ans. The relative shift between object and image when eye is moved sideways.

Date…………

Expt: Wavelength of sodium light by Newton's rings.





Observations and Calculations:

Least count of spherometer = 0.01 mm
Mean distance between the two legs = l
Reading of spherometer on convex surface =
Reading of spherometer on plane surface =
Difference = h
Radius of curvature = R = $l^2/6h + h/2$ = 524 cm
Least count of the microscope = 0.005 cm
Eyepiece adjusted so that 100 scale division = 5 mm
∴ each division = x = .05 mm
eyepiece scale division = y

No. of obs.	Ring No. N	Microscope reading Left	Right	Diameter y x x mm	Square of diameter mm^2	$\lambda = \frac{D_n^2 - D_m^2}{4(n-m)R}$ (cm)
1	8th	22	78	56x.05=2.8	7.84	$\frac{D_{10}^2 - D_8^2}{4(2)524} = 4222 \times 10^{-8}$
2	10th	19	81	62x.05=3.1	9.61	$\frac{D_{12}^2 - D_{10}^2}{4(2)524} = 5128 \times 10^{-8}$
3	12th	16	84	68x.05=3.4	11.56	$\frac{D_{14}^2 - D_{12}^2}{4(2)524} = 5081 \times 10^{-8}$
4	14th	13	87	74x.05=3.7	13.69	

$$\text{Mean } \lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3}{3} = 4810 \times 10^{-8} \text{ cm}$$

Actual value of $\lambda = 5896 \times 10^{-8}$ cm

$$\text{Percentage error} = \frac{\text{Actual value} - \text{Calculated value}}{\text{Actual value}} \times 100 = \text{…… \%}$$

The rings are named after its discoverer, the great scientist once born in millenniums.

Put a prism at the curved surface of a Plano-convex lens. Throw monochromatic light on one side of the prism. Then look from other side broad and bright Newton's rings. Find λ of incident light as in the standard experiment.

Experiment No. 20:

To determine the wavelength of sodium light by Newton's rings.

Apparatus:

Newton's rings apparatus, sodium light, plane-convex lens, spherometer, traveling microscope, convex lens, and glass plate.

Theoretical Background:

The formula is;
$$\lambda = \frac{D_n^2 - D_m^2}{4(n-m)R}$$

where D_n & D_m are the diameters of n^{th} & m^{th} rings seen through the microscope which are made by plano-convex lens

Procedure:

1) *Place plane-convex lens on the glass plate.*
2) *Adjust the beam of sodium light for 45° to focus on plane-convex lens.*
3) *Observe the concentric dark and bright rings through microscope.*
4) *Set the cross-wire at the end of (say) nth dark ring and note it.*
5) *Then read from the other end of diameter of the same ring.*
6) *Measure the diameters of twenty consecutive rings. Combine the first diameter with the eleventh, the second with twelfth, so on.*
7) *Find the radius of curvature R by filling the lines above table.*
8) *Complete all the columns of the table and the lines above the table.*

Precautions:

1. Allow the light to fall normally on the lens.
2. The surfaces of lens and glass plate should be cleansed with spirit.
3. Focus the microscope on the point of contact of lens and the plate.

Sources of Error:

1. The radius of curvature of the lens surface might not be measured exactly.
2. Light might not be incident on the lens normally.
3. Backslash error might be occurred during the screw movement.

Viva Voce:

Q.1 *What are Newton's rings?*

Ans. Circular rings produced by interference due to light reflected from an air film whose thickness increases uniformly.

Q.2 *What phenomenon do the Newton's rings illustrate?*

Ans. It illustrates the phenomenon of interference of light.

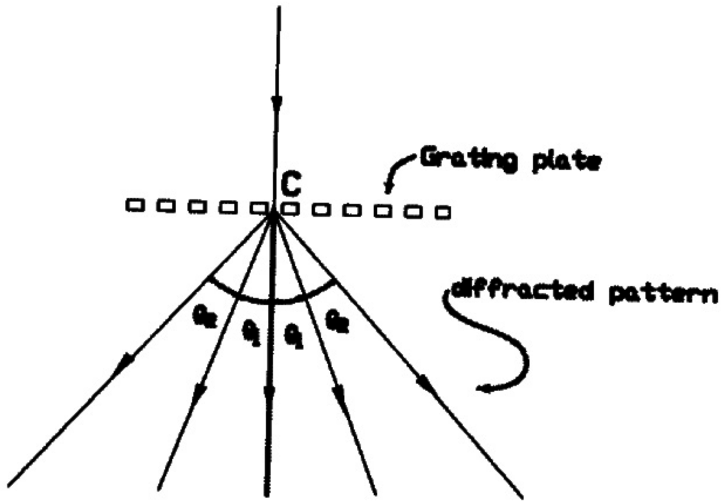
Q.3 *What type of fringes are obtained with white light?*

Ans. Coloured circular fringes.

Date…………

Expt: Wavelength of sodium light by diffraction grating.

Geometrical details of diffraction grating exp.



Observations and Calculations:

Least count of the spectrometer = 1.5 cm

No. of lines on the grating = n = 2400 line/inch

No. of lines per centimeter on the grating = n_1 /2.54 = n

Grating element = d = 1/n = 2.54 /2400 = 1058 x 10^{-6}

No. of obs.	Order of spectrum	Telescope reading		Angle of diffraction			$\lambda = \frac{(a+b)\sin\theta}{n}$
		Right	Left				
	N	R	L	2θ = L - R	θ	Sin θ	cm
1	$I_{n=1}$	*17°16′30″*	*23°51′00″*	*6°34′30″*	*3°17′15″*	0.0573	6067×10^{-8}
2	$II_{n=2}$	*13°55′30″*	*27°9′00″*	*13°13′30″*	*6°30′45″*	0.1151	6091×10^{-8}

Mean λ = 6067×10^{-8} cm

Actual wavelength = 5890×10^{-8} cm

$$\text{Percentage error} = \frac{\text{Actual value} - \text{Calculated value}}{\text{Actual value}} \times 100$$

$$= \frac{5890 - 6079}{5890} \times 100 = 3.2\ \%$$

Sometimes smaller things de-track straight paths, just like diffraction!

Take coarse gratings with a wide spacing. Look for 3rd order spectrum with sodium light. Find λ from the formula d sin θ = nλ. [No. of order possible depend on the width of the grating space. Sin θ cannot greater than 1, so maximum number of order possible cannot be greater than n, from nλ = d ·1, with wide spacing d, we can see 3rd or higher order.]

Experiment No. 21(a):

To determine the wavelength of sodium light by diffraction grating using spectrometer.

Apparatus:

Spectrometer, diffraction grating, sodium light arrangement.

Spectrometer:

A spectrometer consists of three major parts;

(1) Collimator: It is a tube with an adjustable slit at one end and a convex lens at the other. A screw can adjust the position of the slit.

(2) Telescope: It is an astronomical telescope with an eyepiece carrying a cross-section wire. It can be focused with a screw.

(3) Prism Table: It is a circular table of adjustable height and capable of rotation about a vertical axis.

Procedure:

1) *Take the spectrometer and focus for infinity,*
2) *Set the collimator for parallel rays. Make the telescope and collimator in line. Remove parallax between slit and cross-wire.*
3) *Make the image of the slit symmetrical with respect to cross-wire.*
4) *Mount the grating on its table and adjust it.*
5) *Move the telescope on extreme one side. Turn the table so that the grating becomes perpendicular to the collimator. Adjust the grating so that you can see first and second order spectrum from the naked eye.*
6) *Move the telescope for measuring firstly 1st order spectrum on both sides then for 2nd order spectrum. Note these readings.*
7) *Complete the lines above the table and all the columns of the table.*

Precautions:

1. The grating should be vertical.
2. The slit should be narrow.
3. When telescope is set for infinity, it should not be disturbed during expt.

Viva Voce:

Q.1 *What is a diffraction grating?*

Ans. It is a glass plate with several thousand equally spaced and parallel opaque lines ruled on it.

Q.2 *Why is the ruled surface of the grating away from the collimator?*

Ans. It is to avoid refraction after diffraction has taken place.

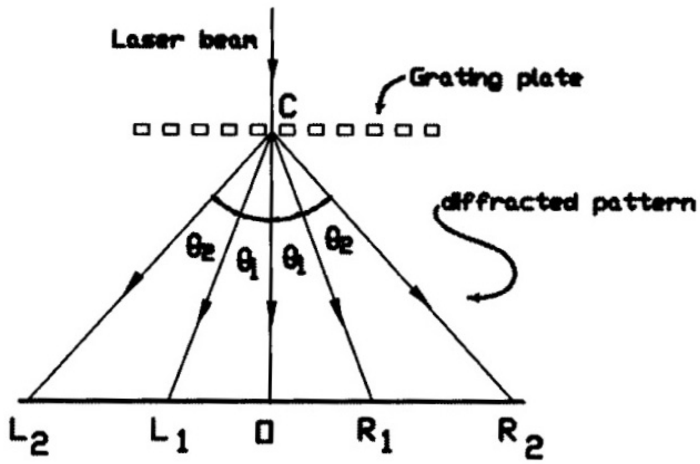
Q.3 *What is diffraction?*

Ans. It is bending of light around the edge of an opening or obstacle.

Date…………

Expt: Wavelength of laser light by diffraction grating.

Geometrical details of diffraction grating exp.



Observations and Calculations:

No. of lines on the grating = n = 2400 line/inch
No. of lines per centimeter on the grating = n_1 /2.54 = n
Grating element = d = 1/n = 2.54 /2400 = 1058 x 10^{-6}

No. of obs.	Order of spectrum	Distance			Angle of diffraction $\tan^{-1}$ OL / OC = θ_L & $\tan^{-1}$ OR / OC = θ_R				$\lambda = \frac{d \sin\theta}{n}$
		normal OC	Left OL	Right OR	θ_L	θ_R	θ_{av}	$\sin\theta_{av}$	
	n	cm	cm	cm	degrees	degrees	degrees		cm
1	*$I_{n=1}$*	246.7	14.1	14.2	3.27°	3.29°	3.28°	0.057	6055 x 10^{-8}
2		257.3	16.5	16.4	3.67°	3.65°	3.66°	.064	6756 x 10^{-8}
1	*$II_{n=2}$*	243.2	28.0	27.9	6.57°	6.54°	6.56°	0.114	6041 x 10^{-8}
2		215.5	27.8	27.7	7.35°	7.32°	7.34°	0.128	6755 x 10^{-8}

Mean λ = 6402 x 10^{-8} cm

Actual wavelength = 6800 x 10^{-8} cm

$$\text{Percentage error} = \frac{\text{Actual value} - \text{Calculated value}}{\text{Actual value}} \times 100$$

$$= \frac{(6800 - 6402)\,10^{-8}}{6800 \times 10^{-8}} \times 100 = 5.8\ \%$$

Science is organized knowledge and wisdom is organized life.

> Take a diffraction grating whose grating element is unknown. Pass laser light of known wavelength. Determine angle of diffraction. Calculate grating element: d = nλ /sinθ

Experiment No. 21(b):

To determine the wavelength of laser light by diffraction grating using a laser.

Apparatus:

Diffraction grating, laser source, metre rod, screen.

Theoretical Background:

A diffraction grating is a glass plate upon which are ruled a number of equally spaced lines. When light falls on it normally, the phenomenon of diffraction occurs. [The condition for diffraction is that, the opening (width of spacing) should be of the order of the wavelength of incident light.]

We define; grating element = d = $\frac{\text{Length of the grating}}{\text{No. of ruled lines on it}}$

Procedure:

1) Take the laser source and adjust its pointer.
2) Mount the grating on its table and adjust the apparatus as in the figure.
3) Make transmitted ray symmetrical with respect to diffraction grating plate.
4) Turn the table so that the grating becomes perpendicular to the laser light.
5) Put a screen at a distance greater than 2 metres from the diffraction grating.
6) Adjust grating so that the rays of 1st & 2nd order spectrum can be seen on screen.
7) Look and note the readings on the screen for 1st and 2nd order spectrum.
8) Calculate the distances from the points taken and put them in the table.
9) Complete the lines above the table and all the columns of the table.
10) Calculate mean λ and % age error by comparing your value with actual value.

Precautions:

1. Take large distance of measurement as compared to the angle.
2. Try to use measuring instrument of high resolving power.
3. The diffraction grating element should be comparable with the order of wavelength of laser light.

Viva Voce:

Q.1 *What is the difference between spectrometer reading and laser light reading?*

Ans. In spectrometer we look through the telescope, but in laser light we look at the screen.

Q.2 *Define laser light.*

Ans. A device which is able to produce a beam of radiation with unusual properties, generally the beam is, coherent monochromatic, parallel with high intensity.

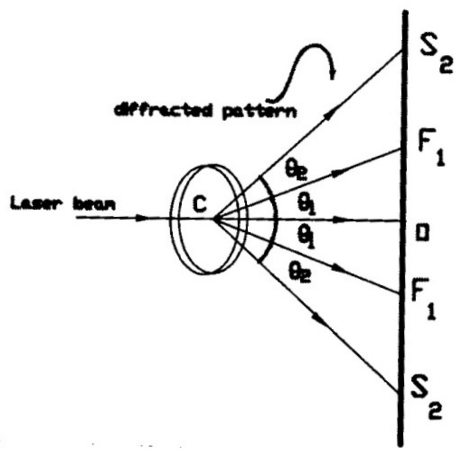
Q.3 *How lasers can be classified?*

Ans. There are three major kind: i) Solid laser, ii) Liquid laser & iii) Gas lasers.

Date…………

Expt: Diameter of a wire or hair using laser.

Geometrical details of diffraction grating exp.



Observations and Calculations:

Wave length of laser light = $\lambda = 6800 \times 10^{-8}$ cm

No. of obs.	Order of spectrum	Distance			Angle of diffraction $\tan^{-1} OF / OC = \theta_1$ & $\tan^{-1} OS / OC = \theta_2$				$d = \frac{n\lambda}{\sin\theta}$
		normal OC	First OF	Second OF	θ_1	θ_1	θ_{av}	$\sin\theta_{av}$	
	n	cm	cm	cm	degrees	degrees	degrees		cm
1	$I_{n=1}$	*230*	*3.1*	*3.1*	*0.77°*	*0.77°*	*0.77°*	*.0134*	*.0049*
2		*255*	*3.4*	*3.4*	*0.76*	*0.76*	*0.76*	*.0133*	*.0051*
1	$II_{n=2}$	OC	OS	OS	θ_2	θ_2	θ_{av}	$\sin\theta_{av}$	*.0050*
		230	*6.3*	*6.3*	*1.57°*	*1.57°*	*1.57°*	*.0274*	
2		*255*	*7.0*	*7.1*	*1.57*	*1.59*	*1.58*	*.0276*	*.0049*

Mean d = = .004975 = 4975×10^{-6} cm

These readings are just for guideline; take your readings more precisely.

Construct a hole or slide wire whose width is such that through which diffraction of laser light is possible. Find λ for 1st order spectrum.

Experiment No. 22:

To measure the diameter of a wire or hair using laser.

Apparatus:

Laser source, wire slide, stand, screen, metre rod.

Theoretical Background:

We measure large diameter (say of some hole) with metre rod or with a vernier calipers. Smaller one (of the order of millimeter), with a micrometer screw gauge. And for smaller than that, we use traveling microscope. When a diameter is comparable with the wavelength of light, we observe the phenomenon of diffraction. Then we can calculate the diameter, from the diffraction properties, by taking positions of 1^{st} or 2^{nd} order spectrum.

Procedure:

1) *Take the laser source and adjust its pointer.*
2) *Mount the wire slide on its table and adjust the apparatus as in the figure.*
3) *Make transmitted ray symmetrical with respect to wire slide.*
4) *Turn the table so that the wire slide becomes perpendicular to the laser light.*
5) *Adjust the wire grating so that the rays of first and second order spectrum can be seen on the screen.*
6) *Note the readings by looking the spots of first order and second order spectrum on the screen. And calculate the distances.*
7) *Complete all the columns of the table. And calculate mean diameter.*

Precautions:

1. The screen upon which laser light falls should be vertical.
2. Take reading of the spot of laser light from the center of the spot.
3. The laser light should be handle in such a way that horizontal beam should fall on the screen.

Viva Voce:

Q.1 *Why we should take long distances for measurement in case of laser light experiments?*

Ans. Because resolving power of the spots on the screen is less than the telescope readings.

Q.2 *What is laser principle?*

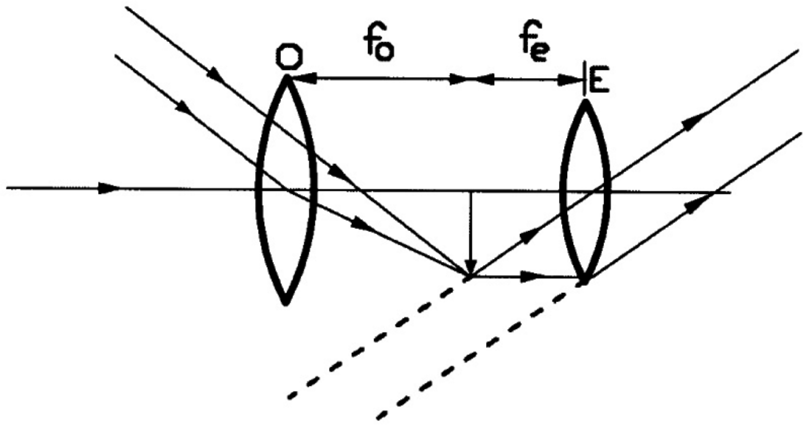
Ans. The light is produced in a process in which de-excitation of an atom is caused by incident photon with the emission of a second photon of the same energy, coherent with original photon.

Q.3 *How many wavelengths are contained in laser light?*

Ans. The laser light is monochromatic light.

Date…………

Expt: Setting up a telescope.



Observations and Calculations:

Approximate focal length objective = F_o = 20 cm
Approximate focal length eyepiece = F_e = 10 cm
Length of knitting needle = l_1 = 30 cm
Distance between two needles = l_2 = 29.3 cm
Index correction for the needles = $l_1 - l_2$ = 0.7 cm

No. of obs.	Positions of				$d = L_2 - L_1$	Distance, l (between O & I)		$f = (l^2 - d^2)/4l$
	Object needle	Image needle	Lens			Observed	Corrected	
	O	I	L_1	L_2		l'	l	
	cm	cm	cm	cm	cm	cm	cm	cm
Eye-piece	*17.9*	*68.8*	*50*	*36.8*	*13.2*	*50.9*	*50.2*	*11.8*
	19	*68.9*	*50*	*40.5*	*9.5*	*49.9*	*49.2*	*12*
	20	*69.4*	*50*	*45.8*	*4.2*	*49.4*	*48.7*	*12.2*
Obje-ctive	*12*	*88.3*	*76*	*68.3*	*7.7*	*76.3*	*77.0*	*19.1*
	6	*79.3*	*72*	*61.2*	*10.8*	*73.3*	*74.0*	*18.1*
	18	*92.2*	*73*	*64.4*	*8.6*	*74.2*	*74.9*	*18.5*

Mean focal lengths : f_o = 18.6 cm & f_e = 12.0 cm
Magnifying power of the telescope = f_o / f_e = 1.55
Length of the telescope = $f_o + f_e$ = 30.6 cm

Galileo made his last astronomical discovery about moon from the telescope he made, before he was sentenced and got blind.

1. Make a telescope with three lenses so that an erect image can be seen (Terrestrial telescope).
2. Find magnifying power of a convex lens. Mount a ruler vertically. Place your eye 25cm apart. Place the convex lens close to your eye. Hold a second ruler behind the lens. Looking at the two rulers simultaneously, compare these scales.

[If 1 cm have same visual angle as 2cm, then magnification is 2]

Experiment No. 23:

Setting up a telescope and determination of its magnifying power and length.

Apparatus:

Two convex lenses, uprights, metre rod, parallax needles, knitting needle.

Theoretical Background:

A simple astronomical telescope consists of two convex lenses; an objective (of large focal length) and an eyepiece (of short focal length). The objective forms a real and inverted image of a far distant object. The eyepiece is adjusted so that the image formed should be at its focus. The eyepiece behaves as a magnifying glass, the image can be seen by placing the eye close to get final image at the least distance of distinct vision.

The magnifying power is, $M = \frac{f_o}{f_e} = \frac{\text{focal length of the objective}}{\text{focal length of the eyepiece}}$

Procedure:

1) *Select two lenses having one with short and other with long focal length.*
2) *Find approximate focal lengths of both lenses and fill lines above the table.*
3) *Find the correct focal lengths of objective lens (longer focal length), and the eyepiece lens (shorter focal length) and fill the tables.*
4) *Mount the objective and eyepiece on the lens holders and adjust their heights. Place an object needle far away (> $2f_o$) from the objective.*
5) *Place the parallax needle just beyond the focus f_o . Remove the parallax.*
6) *Place the eyepiece such that distance between needle and eyepiece is equal to f_e .*
7) *Adjust position of the eyepiece to get a clear image of the object needle tip.*
8) *Remove the object needle. Now adjust both lenses for the focus at infinity.*
9) *Measure the distance L between the objective and the eyepiece.*
10) *Calculate magnifying power of the telescope from the formula.*

Precautions:

1. The focal length of objective should be larger than the eyepiece.
2. The optical centers of both lenses should be along the same line.
3. The eye should be kept close to the eyepiece.

Viva Voce:

Q.1 *What is a telescope?*

Ans. An instrument for looking distant objects.

Q.2 *What is a magnifying glass?*

Ans. A convex lens of small focal length behaves as a simple microscope.

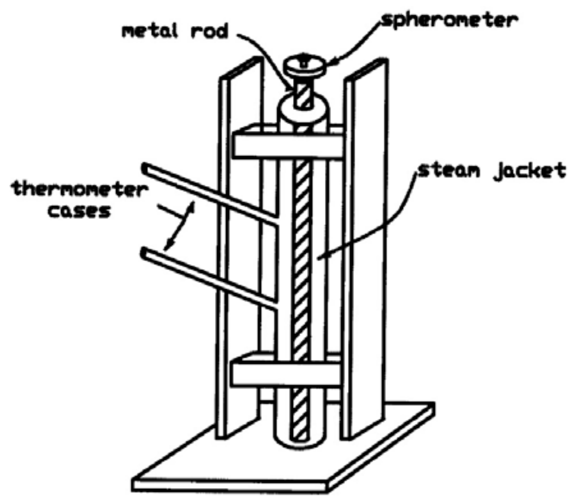
Q.3 *Define magnifying power of a telescope.*

Ans. Ratio of angle subtended by image at the eye as seen through the telescope to the angle of the object at the unaided eye, both lying at infinity.

Date…………

Expt: Linear expansion by Pullinger's App.

Pullinger's App:



Observations and Calculations:

Initial length of the rod = L = 100 cm
Initial temperature of the rod = t_1 = 32 °C
Final temperature of the rod = t_2 = 98 °C
Rise in temperature = $t_2 - t_1 = t$ = 66 °C
Pitch of the spherometer = 0.5 mm
No. of divisions of the circular scale = 100
Least count of the spherometer = 0.005 mm

Table for Spheromaeter:

No. of obs.	Initial reading (with cold water)	Final reading (when steam is passed)	Increase in length (Expansion)
	mm	mm	mm
1	1.45	1.56	0.11
2	1.25	1.37	0.12
3	1.35	1.47	0.12

Mean expansion = Δl = 0.1166 mm

Coefficient of linear expansion:

$$\alpha = \frac{\Delta l}{L \times \Delta t} = \frac{0.1166}{100 \times 66} = 17.66 \times 10^{-6}\ ^{o}C^{-1}$$

Correct value (for brass) = $19 \times 10^{-6}\ ^{o}C^{-1}$

Percentage error = 7.02 %

Every man' s task is his life preserver.

Make a thermocouple (two metals joined together) and compare its bending for different temperatures.

Experiment No. 24:

To find the coefficient of linear expansion of the material of a rod by Pullinger's apparatus.

Apparatus:

Pullinger's apparatus, spherometer, two thermometers, boiler, rubber tubing, meter scale.

Theoretical Background:

We have: $\alpha = \Delta L / (L_o \times \Delta t)$,

where L_o = Length of rod, Δt = change in temperature,

ΔL = change in length of rod & α = coefficient of linear expansion.

Procedure:

1) *Measure the length of the rod and replace it in the frame.*
2) *Insert two thermometers into the two side tubes.*
3) *Pass the cold water through the tube jacket and note the initial thermometer readings. Take their mean value.*
4) *Place the spherometer on the glass plate with its central leg just touching the top end of the rod. Note the reading.*
5) *Pass steam through the tube. When temperature becomes steady, note final spherometer reading and the temperature. Repeat twice.*
6) *Complete the table and the lines. Calculate coefficient of linear expansion.*

Precautions:

1. The thermometer bulb should just touch the rod.
2. Temperature should be noted when it becomes steady.
3. Measurements should be made accurately.

Sources of Error:

1. The loss of heat due to radiation and convection cannot be avoided.
2. The temperature of the rod will be not be exactly same near the upper end.
3. Less time of heating might not be able to produce constant temperature throughout the rod.

Viva Voce:

Q.1 *What is coefficient of linear expansion?*

Ans. It is increase in unit length, when heated through 1 ^oC.

Q.2 *Why should the rod be supported on a heavy iron base?*

Ans. To ensure that the rod will expand upwards only.

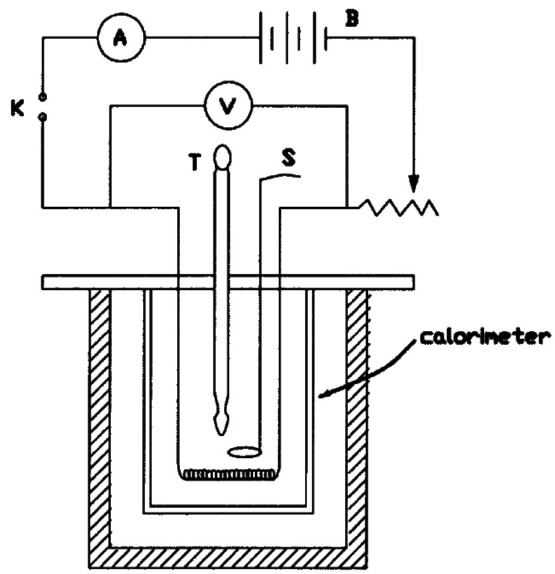
Q.3 *Is co-efficient of linear expansion same for all metals?*

Ans. No. It is different for different metals.

Date…………

Expt: 'J' by electrical method.

Joule's calorimeter:



Observations and Calculations:

Specific heat of copper calorimeter = c_1 = 0.095 cal/gm ^oC
Mass of calorimeter + stirrer = m_1 = 80 gm
Mass of calorimeter + stirrer + water = m_2 = 125 gm
Mass of water = $m_2 - m_1$ = m = 45 gm
Specific heat of water = c = 1.0 cal/gm ^oC
Initial temperature of water = T_1 = 29 ^oC
Final temperature of water = T_2 =34.5 ^oC
Rise in temperature = $\Delta T = T_2 - T_1$ = 5.5 ^oC
Current from ammeter = I = 1.0 amp
Voltage from voltmeter = V = 5.3 volts
Time for which current flows = t = 4 min = 240 sec
Mechanical equivalent of heat = $J = \frac{V\,I\,t}{(mc + m_1 c_1)\,\Delta T} = \frac{5.3 \text{x} 1 \text{x} 240}{(45\text{x}1 + 80\text{x}0.095)\, 5.5}$

= 4.397 joules/cal
= 4.3 x 10^7 ergs/cal

Actual value = 4.2 x 10^7 ergs/cal

Percentage error = 4.7 %

<u>Hello!</u> Best of luck in your practical exams.

Calculate 'J' for A.C. voltage by taking an immersion rod.

Experiment No. 25:

To measure the mechanical equivalent of heat by electrical method.

Apparatus:

Joule's calorimeter, ammeter, voltmeter, thermometer, key, rheostat, stop clock, balance, weight box, battery, sand paper, connecting wires.

Theoretical Background:

We have: J = W /Q, where J is mechanical equivalent of heat,
Q = amount of heat gained by calorimeter and the liquid,
& W = P x t = V I t = electrical energy supplied in Joules.

Procedure:

1) *Weigh the calorimeter with stirrer.*
2) *Fill the calorimeter with water so that the resistance coil can easily immersed in it. Weigh again.*
3) *Make connections according to circuit diagram without battery with open key.*
4) *Insert a thermometer in the calorimeter. Note initial temperature.*
5) *First circuit to be checked by the teacher, then attaches the battery.*
6) *Close the key and at the same time start stop clock.*
7) *Check and note for smooth current and voltage.*
9) *Wait till the temperature rises 4 or 5 ^{o}C then stop the current and the stop clock.*
10) *Record all readings & calculate mechanical equivalent of heat 'J' from formula.*

Precautions:

1. A constant current should pass with adjustment of rheostat.
2. Coil should be covered completely with water.
3. Voltage applied should not exceed 10 volts to avoid electrolysis.

Sources of Error:

1. Radiation of heat cannot be avoided in this experiment.
2. Corrections might not be applied for ammeter and voltmeter readings.
3. The liquid might not be stirred uniformly during the experiment.

Viva Voce:

Q.1 *What is meant by J ?*
Ans. It is mechanical work done to produce one calorie of heat.
Q.2 *What type of heating coil should be used?*
Ans. Constantan, Manganin or Eureka wire.
Q.3 *What is Joules law in electricity?*
Ans. When a current flows in a conductor, heat produced in it is directly proportional to square of current and time for which current passes.

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Part II

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General Instructions for Electricity Experiments

To avoid shocks:

Please check that power sources are disconnected before you touch any wires or components in the circuit. Even with circuits you think are not `live,' try to develop the habit of working one-handed, with the other hand either in your pocket or in your lap.

To avoid current and power overloads:

If there is some doubt how much current is in a branch of a circuit, set the adjustable resistors which affect that branch to values which will limit the current as much as
possible. Put an ammeter of sufficiently high range in the branch. Then slowly change the resistor settings to increase the current by watching on the meter readings.

To know the limitations of equipment:

Every circuit component has limits of current, voltage, or power beyond which it will not work properly and may be damaged. These limitations are clearly stated in the manufacturer's catalogs which should be in the lab. Find these values and record them in your lab notebook before wiring and powering the circuits. If some information is not available in the files, ask the instructor for it.

To measure with voltmeters and ammeters:

Note the polarities of the meter probe leads with respect to the battery polarity of the circuit. A good voltmeter has very high resistance, often in mega ohms. When it is connected properly across a circuit element the voltmeter doesn't divert much of the circuit's current. So the currents and potentials existing in the circuit are not changed so much ..

An ideal ammeter has a very low resistance. When it is connected
in series with a circuit element, it doesn't add significant resistance to the circuit. Therefore the currents and potentials existing in the circuit are not changed much. But most ammeters are not ideal and change the circuit current.

When an ammeter is improperly connected, in parallel with a circuit element, its low resistance allows considerable current to be diverted through the meter, possibly damaging the meter or the circuit. Even if the current is within the range of the meter.
When a voltmeter is improperly connected, in series with a circuit element, its high resistance limits the current in that branch of the circuit to a very low value. This alters the currents and potentials of the circuit from their original values. The meter usually won't be damaged, and will indicate a voltage very near to zero.

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How Electrical Current Affects the Human Body

Three primary factors affect the severity of the shock a person receives when he or she is a part of an electrical circuit:

1)Amount of current flowing through the body (measured in amperes).
2) Path of the current through the body.
3) Length of time the body is in the circuit.

Other factors that may affect the severity of the shock are:

1) The voltage of the current. 2) The presence of moisture in the environment.
3) The phase of the heart cycle when the shock occurs.
4) The general health of the person prior to the shock.

Effects can range from a barely perceptible tingle to severe burns and immediate cardiac arrest. Although it is not known the exact injuries that result from any given amperage, the following table demonstrates this general relationship for a 60-cycle, hand-to -foot shock of one second's duration:

Current level (mA)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation. May be dangerous under some conditions.
5mA	Slight shock felt; not painful but disturbing. Average individual can let go.
6mA -16mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17mA -99mA	Extreme pain, respiratory arrest, severe muscular contractions. . If individual cannot let go death possible.
100mA -2000mA	Cardiac arrest, internal organ damage, and severe burns. Death is probable.

Under dry conditions, human skin is very resistant. Wet skin dramatically drops the body's resistance.

Dry Conditions: Current = Volts / Ohms = 120 / 100,000 = 1 mA
a barely perceptible level of current

Wet conditions: Current = Volts / Ohms = 120 / 1,000 = 120 mA
sufficient current to cause cardiac problem.

Time duration: When muscular contraction caused by stimulation does not allow the victim to free himself from the circuit, even relatively low voltages can be extremely dangerous, because the degree of injury increases with the length of time the body is in the circuit.

100mA for 3 seconds = 900mA for 0.03 seconds - in causing cardiac problem.
Note that a difference of less than 100 milli- amperes exists between a current that is barely perceptible and one that can kill.

References:

1) NIOSH [1998]. Worker Deaths by Electrocution; A Summary of NIOSH Surveillance and Investigative Findings. Ohio: US Health and Human Services.
2) Greenwald EK [1991]. Electrical Hazards and Accidents - Their Cause and Prevention. New York: Van Nostrand Reinhold

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The Fatal Current

The most obvious risk from electricity is electrocution through contact with a live circuit. This is where an electrical current flows through the body which can result in the heart stopping to work (cardiac arrest).

Strange as it may seem, most fatal electric shocks happen to people who should know better. Here are some electro-medical facts that should make you think twice before taking that last chance.

Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

It's The Current That Kills

Offhand it would seem that a shock of 10,000 volts would be more deadly than 100 volts. But this is not so! Individuals have been electrocuted by appliances using ordinary house currents of 110 volts and by electrical apparatus in industry using as little as 42 volts direct current. The real measure of shock's intensity lies in the amount of current (amperes) forced though the body, and not the voltage. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current.

While any amount of current over 10 milliamps (0.01 amp) is capable of producing painful to severe shock, currents between 100 and 200 mA (0.1 to 0.2 amp) are lethal. Currents above 200 milliamps (0.2 amp), while producing severe burns and unconsciousness, do not usually cause death if the victim is given immediate attention. Resuscitation, consisting of artificial respiration, will usually revive the victim.

From a practical viewpoint, after a person is knocked out by an electrical shock it is impossible to tell how much current has passed through the vital organs of his body. Artificial respiration must be applied immediately if breathing has stopped.
The actual resistance of the body varies depending upon the points of contact and the skin condition (moist or dry). Between the ears, for example, the internal resistance (less the skin resistance) is only 100 ohms, while from hand to foot is closer to 500 ohms. The skin resistance may vary from 1000 ohms for wet skin to over 500,000 ohms for dry skin.

References:
New Jersey State Council of Electrical Contractors Associations, Inc.
Bulletin VOL. 2, NO. 13
February, 1987
Submitted by Paul Giovinazzo

Method for plotting a graph

Step 1: Selecting independent and dependent variables

a) Find the values, which are changing independently. It will be your independent variable.

b) Find the values that depend upon the independent variable. It will be your dependent variable.

Step 2: Making the Scale

a) Take difference of highest and lowest values.

b) Divide that difference by 6 [= No. of big divisions] for X-axis. Make that calculated difference a round figure. Write it down as the Scale on top right corner of the graph paper.

c) Divide the difference by 8 [= No. of big divisions] for Y-axis. Make that calculated difference a round figure. Write it down as Scale on top right corner.

Step 3: Writing numbers along the Axes

a) Take lowest reading and write its round figure on the origin O.

b) Write down the values along the X-axis and Y-axis below the bold lines (big squares) progressively. That is, after adding the big division's value in each next value.

Step 4: Plotting the points [*Please look last reading (R_6) on page 11*]

a) First divide big division's scale by 10, to get small division's (or squares) value. Make small division's scale for X- and Y-axis.

b) Take a point from X-values. Find its position along big divisions [step 3(b)] for its whole figure part of the point [B.d. value].

c) Multiply this point's fractional part [s.d. multiplier] with small division's scale, and add to B.d. value [step 4(b)]. Then locate the position of the point along X-axis.

d) Take corresponding Y-value point. Repeat the above steps (b) & (c).

e) Locate intersection of both values in the graph paper. Mark this point with a dot and encircle it.

f) Similarly plot all the points.

Step 5: Drawing the Curve

i) For straight line graph

a) Take a transparent ruler.

b) Put the ruler in such a way that maximum points are symmetrical or pass through it.

c) Finally draw the line which is called Curve.

ii) If it is not straight line graph, then draw a smooth free hand curve passing symmetrically through large number of points.

Step 6: Writing Graph Title

Finally write down in bold letters, 'Graph between (say) A and B' on top location, starting from left side of the sheet.

Genius is one percent inspiration and ninety-nine percent perspiration. –Edison

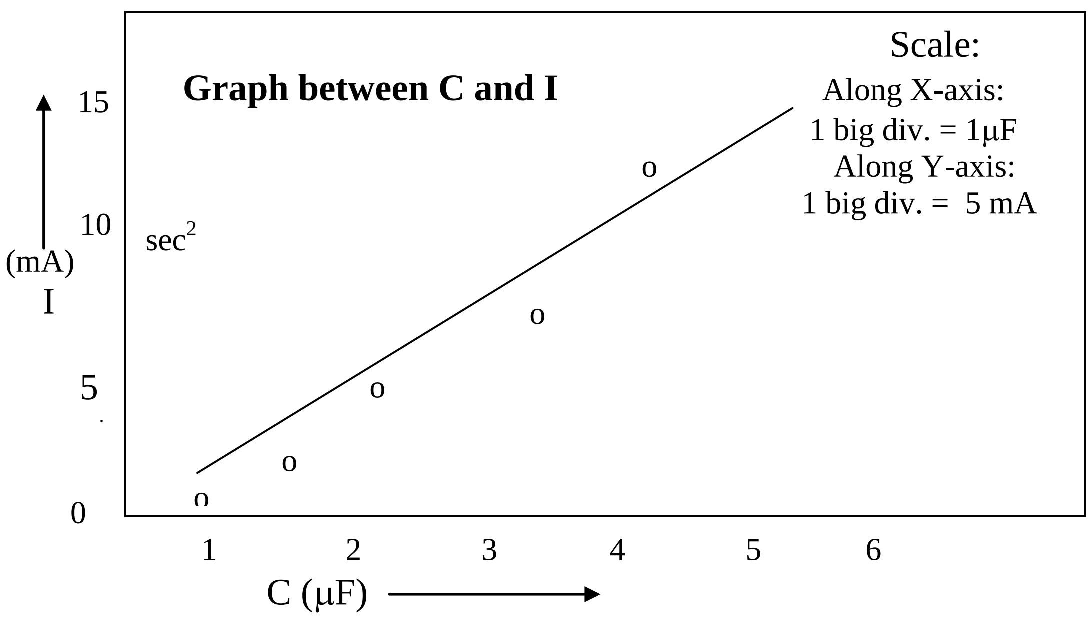
Date……………

Plotting graphs.

<u>Graph between C & I</u> :

Capacity (μF)	C	3.3	2.2	1	1.5	5.5	2.5	4.3	3.7	4.8
Current (mA)	I	12	9	6	7	14	10	13	12	13

Typical graph:



Imagination is more important than knowledge. –Albert Einstein

Experiment A:

To plot a graph between current and capacity.

Materials:

Graph papers, lead pencil, rubber, sharpener, and transparent ruler.

Procedure:

1) *Draw the two axes with a sharp pencil, at right angles to each other taking a point O as origin at the left bottom corner of the graph paper.*
2) *Take independent variable (capacity) along X-axis and dependent (current) along Y-axis.*
3) *Select suitable scales for both axes, so that all the graph paper would be covered.*
4) *Mark the scale on each axis, so that the value after every ten divisions is specified.*
5) *Start with a certain value represented along the X-axis and then locates the corresponding point along the Y-axis. Mark this point by a dot and encircle it. Similarly plot all points for different values of the two quantities.*
6) *Draw a smooth free hand curve passing symmetrically through large number of points. For straight line graph then draw with a transparent ruler so that maximum points pass through the line or symmetrical with it.*

Precautions:

1. A sharp pencil should be used.
2. Take along X-axis independent variable and along Y-axis dependent.
3. Small circles should be drawn around the plotted points.

Viva Voce:

Q.1 *What is a graph?*

Ans. A graph is a curve, which shows relation between an independent variable and its dependent variable.

Q.2 *What is variables?*

Ans. These are the quantities, which do not have fixed values.

Q.3 *What are independent and dependent variables?*

Ans. Independent variable is that which we vary independently and dependent variable is that which vary according to the variation depending upon independent variable.

Graph Illustration

V and I graph

V (volts)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.07
I (mA)	0	0.12	0.22	0.28	0.32	0.36	0.40	0.42	0.44	0.45

(Read method for plotting a graph on page 7)

Step 1: taking V along X-axis & I along Y-axis

Step 2:

big division

$V \rightarrow \frac{1 - 0.1}{6} = \frac{0.9}{6} = 0.15 \cong 0.2 \Rightarrow B.d = 0.2 \;\&\; s.d = 0.02$

small division

$I \rightarrow \frac{0.46 - 0.12}{8} = \frac{0.34}{8} \cong 0.043 \cong .05 \cong .07 \Rightarrow B.d = 0.07 \;\&\; s.d = 0.007$

Step 4:

$V_1 \rightarrow 0$ & $I_1 \rightarrow 0$

$V_2 \rightarrow 0 + 5x\ .02 = 0.1$ & $I_2 \rightarrow .07 + 7.14x.007 = 0.12$

$V_3 \rightarrow 0.2$ & $I_3 \rightarrow .21 + 1.4x.007 = 0.22$

$V_4 \rightarrow 0.2 + 5x\ .02 = .3$ & $I_4 \rightarrow 0.28$

$V_5 \rightarrow 0.4$ & $I_5 \rightarrow 0.28 + 5.7x.007 = 0.32$

$V_6 \rightarrow 0.4 + 5x\ .02 = .5$ & $I_6 \rightarrow 0.35 + 1.4x.007 = 0.36$

$V_7 \rightarrow 0.6$ & $I_7 \rightarrow 0.35 + 7.14x.007 = 0.40$

$V_8 \rightarrow 0.6 + 5x\ .02 = .7$ & $I_8 \rightarrow 0.42$

$V_9 \rightarrow 0.8$ & $I_9 \rightarrow 0.42 + 2.86x.007 = 0.44$ 5.92

$V_{10} \rightarrow 1 + 2.5x\ .02 = 1.05 < 1.07$ a little higher point
2 & ½ s.d

& $I_{10} \rightarrow 0.42 + 5.5x\ .007 = 0.46 > 0.45$ a little lower point
5 & ½ s.d

Scale:
Along X-axis:
1 big div = 0.2 volts
Along Y-axis:
1 big div = 0.07 mA

Evaluation

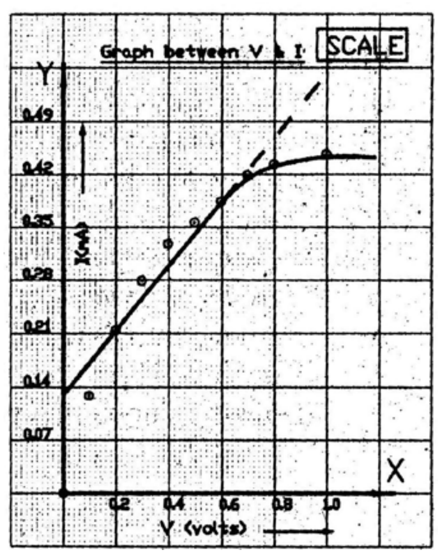
Finding:

Time rate of energy dissipation across tungsten filament (resistor)

$\frac{W}{t} = P = V\,I$

$= 0.7 \times 0.42$

$= 0.3$ watts



Graphs arrange numerical information into a picture.

R and 1/V graph

R (ohms)	0	500	1000	1500	2000	2500
1/V (volts^{-1})	0.66	0.76	0.90	1.00	1.11	1.25

(Read method for plotting a graph on page 7)

Step 1: taking R along X-axis & 1/V along Y-axis

Scale:
Along X-axis:
1 big div = 1000 ohms
Along Y-axis:
1 big div = 0.2 volt^{-1}

Step 2:

$R \rightarrow \frac{2500 - 0}{3} = 833 \cong 1000 \Rightarrow$ B.d = 1000 & s.d = 100

$1/V \rightarrow \frac{1.25 - 0.66}{4} = 0.15 \cong 0.2 \Rightarrow$ B.d. = 0.2 & s.d. = 0.02

Step 4:

$R_1 \rightarrow 0$ & $1/V \rightarrow 0.6 + 3 \times 0.02 = 0.66$

$R_2 \rightarrow 100 \times 5 = 500$ & $1/V \rightarrow 0.6 + 8 \times 0.02 = 0.76$

$R_3 \rightarrow 1000$ & $1/V \rightarrow 0.8 + 5 \times 0.02 = 0.90$

$R_4 \rightarrow 1000 + 100 \times 5 = 1500$ & $1/V \rightarrow 1.00$

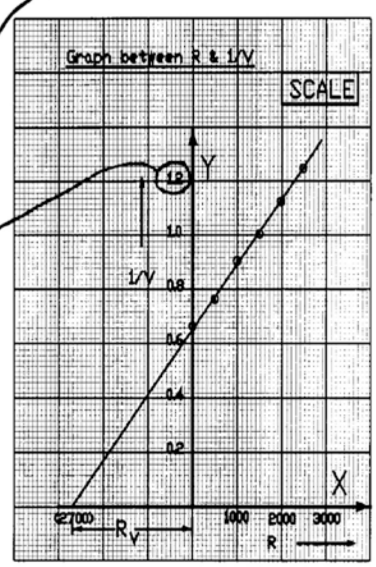
$R_5 \rightarrow 2000$ & $1/V \rightarrow 1 + 5.5 \times 0.02 = 1.11$

$R_6 \rightarrow 2000 + 100 \times 5 = 2500$ & $1/V \rightarrow \boxed{1.2} + (2.5) \times \boxed{0.02} = \boxed{1.25}$

How to find s.d. multiplier

$$\frac{\text{Plot value} - \text{B.d. value}}{\text{s.d.}}$$

$$= \frac{1.25 - 1.2}{0.02} = \frac{0.05}{0.02} = 2.5$$



Evaluation

Finding:

Value of R_V from graph:

$R_{27} \rightarrow 100 \times 27 = 2700$ ohms

Increasing straight line shows that both values are directly proportional to each other.

Absolute Temperature & Thermister Resistor

T (K)	289	293	303	313	323	333	343
R (KΩ)	6	5	3	2.5	1	0.5	0.2

(Read method for plotting a graph on page 7)

Step 1: taking T along X-axis & R along Y-axis

Scale:
Along X-axis:
1 big div = 10 K
Along Y-axis:
1 big div = 1 K Ω

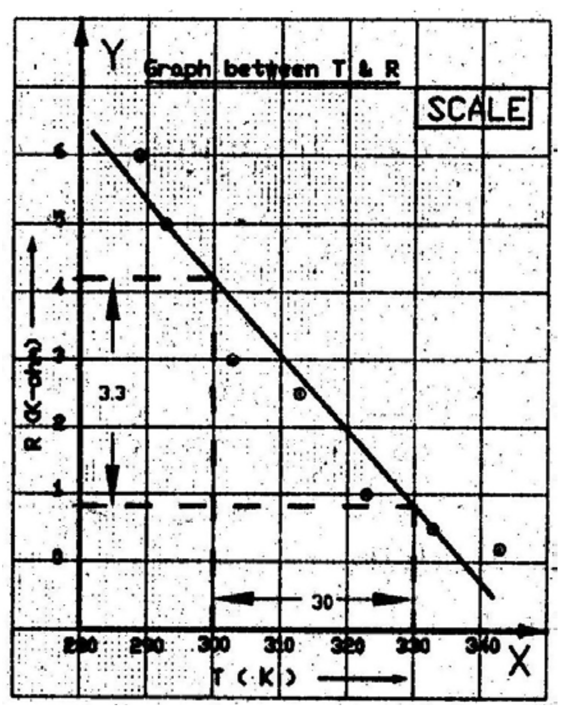
Step 2:

$T \rightarrow \frac{343 - 289}{6} = 9 \cong 10 \Rightarrow$ B.d = 10 & s.d = 1

$R \rightarrow \frac{6 - 0.2}{8} = 0.73 \cong 1 \Rightarrow$ B.d. = 1 & s.d. = 0.01

Step 4:

$T_1 \rightarrow 289$ & $R_1 \rightarrow 6$
$T_2 \rightarrow 293$ & $R_2 \rightarrow 5$
$T_3 \rightarrow 303$ & $R_3 \rightarrow 3$
$T_4 \rightarrow 313$ & $R_4 \rightarrow 2.5$
$T_5 \rightarrow 323$ & $R_5 \rightarrow 1$
$T_6 \rightarrow 333$ & $R_6 \rightarrow 0.5$
$T_7 \rightarrow 343$ & $R_7 \rightarrow 0.2$



Evaluation

Finding:

The slope from graph:

$\Delta R / \Delta T = 3.3 / 30$

$= 0.11 \Omega K^{-1}$

We define slope of a line as tan θ, where θ is the inclination of a line

Distance verses tan θ graph

x(cm)	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14
tanθ	.27	.58	.84	1.15	1.57	1.92	2.41	5.14	3.17	2.41	2.05	1.19	.58	.38	.27

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 5 cm
Along Y-axis:
1 big div = 0.8

Step 1: taking x along X-axis & tan θ along Y-axis

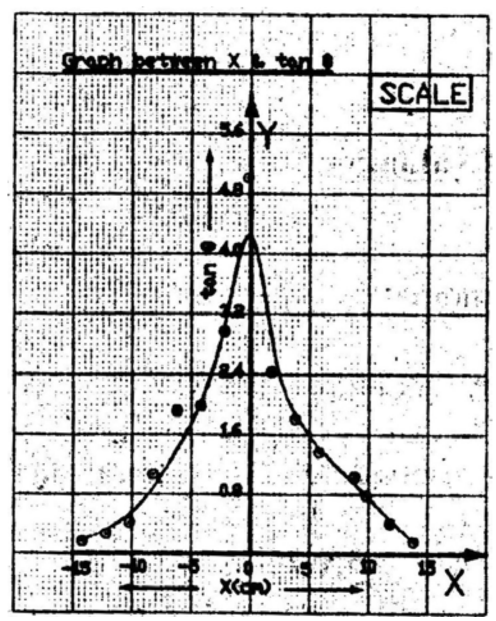
Step 2:

$x \rightarrow \frac{14-0}{3} = 4.67 \cong 5 \Rightarrow$ B.d = 5 & s.d = 0.5

$\tan\theta \rightarrow \frac{5.14-0.27}{8} = 0.61 \cong 0.8 \Rightarrow$ B.d. = 0.8 & s.d. = 0.08

Step 4:

$x_1 \rightarrow 10+8x.5=14$ & $\tan\theta_1 \rightarrow 3.37x.08 = 0.27$
$x_2 \rightarrow 10+4x.5=12$ & $\tan\theta_2 \rightarrow 7.25x.08=0.58$
$x_3 \rightarrow 10$ & $\tan\theta_3 \rightarrow .8+ .5x.08=.84$
$x_4 \rightarrow 5+6x.5=8$ & $\tan\theta_4 \rightarrow .8+4.37x.08=1.15$
$x_5 \rightarrow 5+2x.5=6$ & $\tan\theta_5 \rightarrow .8+ 9.62x.08=1.57$
$x_6 \rightarrow 8x.5= 4$ & $\tan\theta_6 \rightarrow 1.6 +4x.08=1.92$
$x_7 \rightarrow 4x.5=2$ & $\tan\theta_7 \rightarrow 2.4+.12x.08= 2.41$
$x_8 \rightarrow 0$ & $\tan\theta_8 \rightarrow 4.8 +4.25x.08=5.14$
$x_9 \rightarrow -4x.5=-2$ & $\tan\theta_9 \rightarrow 2.4+9.62x.08=3.17$
$x_{10} \rightarrow -8x.5= -4$ & $\tan\theta_{10} \rightarrow 2.4+.12x.08= 2.41$
$x_{11} \rightarrow -(5+2x.5)=-6$ & $\tan\theta_{11} \rightarrow 1.6+5.62x.08=2.05$
$x_{12} \rightarrow -(5+6x.5)=-8$ & $\tan\theta_{12} \rightarrow .8+4.67x.08=1.19$
$x_{13} \rightarrow -10$ & $\tan\theta_{13} \rightarrow 7.25x.08= .58$
$x_{14} \rightarrow -(10+4x.5)=-12$ & $\tan\theta_{14} \rightarrow 4.75x.08= .38$
$x_{15} \rightarrow -(10+8x.5)=-14$ & $\tan\theta_{15} \rightarrow 3.37x.08=.27$



Evaluation

Finding:

The distance *x* at slope 2.

Checking the value along X-axis corresponding to,

$\tan\theta = 2$,

it is equal to 3.5 cm

It is not must that you follow my method of manipulation, you may adopt your own.

Charging of a capacitor

t (sec)	0	4	8	18	25	33
V (volts)	0	5	10	12	12.5	13

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 5 sec
Along Y-axis:
1 big div = 2.5 volts

Step 1: taking t along X-axis & V along Y-axis

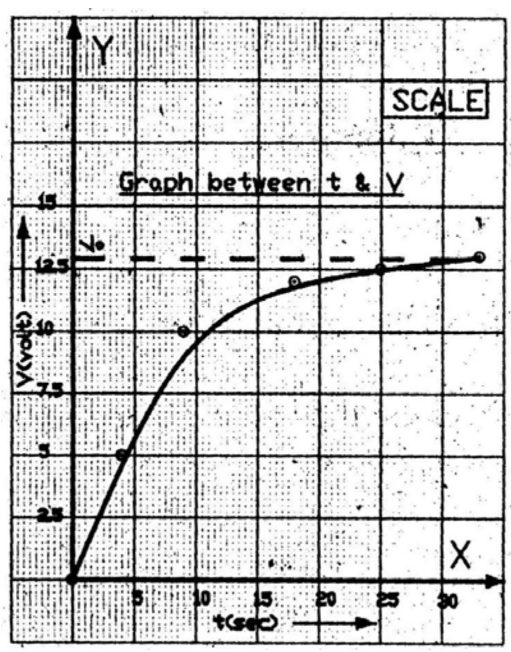
Step 2:

$t \rightarrow \frac{33-0}{6} = 4.12 \cong 5 \Rightarrow$ B.d = 5 & s.d = 0.5

$V \rightarrow \frac{13-0}{8} = 2.16 = 2.5 \Rightarrow$ B.d. = 2.5 & s.d. = 0.25

Step 4:

$t_1 \rightarrow 0$ & $V_1 \rightarrow 0$
$t_2 \rightarrow 8x\ .5=4$ & $V_2 \rightarrow 5$
$t_3 \rightarrow 5+6x\ .5= 8$ & $V_3 \rightarrow 10$
$t_4 \rightarrow 15+ 6x\ .5 = 18$ & $V_4 \rightarrow 10 + 8x\ .25 = 12$
$t_5 \rightarrow 25$ & $V_5 \rightarrow 12.5$
$t_6 \rightarrow 30 + 6x\ .5 = 33$ & $V_6 \rightarrow 12.5 +2x\ .25 = 13$



Evaluation

Finding:

The maximum voltage V_o

Corresponding to maximum value,

V_o = 13 volts

Not a good result. Sources of error might be in readings, or plotting the graph.

Discharging of a capacitor

t (sec)	0	2	6	9	20	28	30	37
V(volt)	13	10	5	2.5	2	0.5	0.25	0

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 7 sec
Along Y-axis:
1 big div = 2.5 volts

Step 1: taking t along X-axis & V along Y-axis

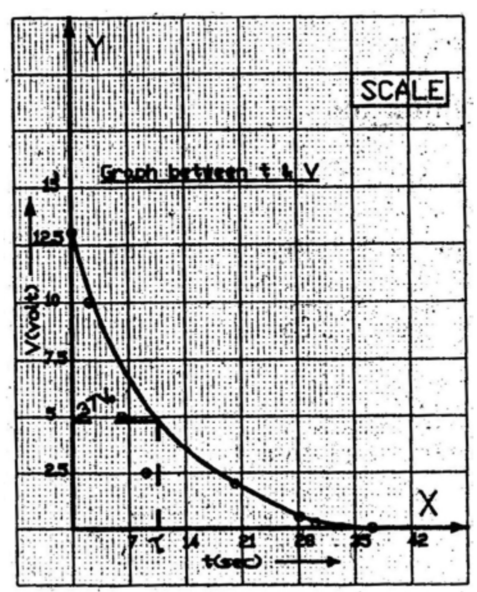
Step 2:

$t \rightarrow \frac{37-0}{6} = 6.167 \cong 7 \Rightarrow$ B.d = 7 & s.d = 0.7

$V \rightarrow \frac{13-0}{8} = 2.16 = 2.5 \Rightarrow$ B.d. = 2.5 & s.d. = 0.25

Step 4:

$t_1 \rightarrow 0$ & $V_1 \rightarrow 12.5 + 2x\ .25 = 13$
$t_2 \rightarrow 2.86x\ .7 = 2$ & $V_2 \rightarrow 10$
$t_3 \rightarrow 8.57x\ .7 = 6$ & $V_3 \rightarrow 5$
$t_4 \rightarrow 7 + 2.86x\ .7 = 9$ & $V_4 \rightarrow 2.5$
$t_5 \rightarrow 14 + 8.57x\ .7 = 20$ & $V_5 \rightarrow 8x\ .25 = 2$
$t_6 \rightarrow 28$ & $V_6 \rightarrow 2x\ .25 = 0.5$
$t_7 \rightarrow 28 + 2.86x\ .7 = 30$ & $V_7 \rightarrow 1x\ .25 = 0.25$
$t_8 \rightarrow 35 + 2.86x\ .7 = 37$ & $V_8 \rightarrow 0$



Evaluation

Finding:

Time constant τ:

Corresponding to $0.37V_o$,

The value along X-axis is,

τ = 10.64 sec

Decreasing straight line shows inversely proportional & decreasing curved line shows exponentially decreasing.

Characteristics of semi-conductor diode

Forward characteristics

V (volt)	1	2	3	4	5	6	7	8	9	10
I (mA)	0	0	0	0	0.25	0.75	1.25	1.75	2.25	2.75

Reverse characteristics

V (volt)	1	2	3	4	5	6	7	8	9	10
I (μA)	10	15	28	30	50	91	140	190	239	290

(Read method for plotting a graph on page 7)

Forward Bias
Scale:
Along X-axis:
1 big div = 4 volts
Along Y-axis:
1 big div = 0.9 mA

Step 1: taking V along X-axis & I along Y-axis

Step 2:

$V \rightarrow \frac{10-1}{3} = 3 \cong 4 \Rightarrow$ B.d = 4 & s.d = 0.4

For Forward Bias

$I \rightarrow \frac{2.75-0}{4} = 0.69 \cong 0.9 \Rightarrow$ B.d. = 0.9 & s.d. = 0.09

For Reverse Bias

$I \rightarrow \frac{290-10}{4} = 70 \cong 100 \Rightarrow$ B.d. = 100 & s.d. = 10

Reverse Bias
Scale:
Along X-axis:
1 big div = 4 volts
Along Y-axis:
1 big div = 100μA

Step 4:

	Forward Bias	Reverse Bias
$V_1 \rightarrow 2.5x.4 = 1$	& $I_1 \rightarrow 0$	& $I_1 \rightarrow 1x10 = 10$
$V_2 \rightarrow 5x.4 = 2$	& $I_2 \rightarrow 0$	& $I_2 \rightarrow 1.5x10 = 15$
$V_3 \rightarrow 7.5x.4 = 3$	& $I_3 \rightarrow 0$	& $I_3 \rightarrow 2.8x10=28$
$V_4 \rightarrow 10x.4 = 4$	& $I_4 \rightarrow 0$	& $I_4 \rightarrow 3.0x10=30$
$V_5 \rightarrow 12.5x.4 = 5$	& $I_5 \rightarrow 2.78x.09 = 0.25$	& $I_5 \rightarrow 5x10=50$
$V_6 \rightarrow 15x.4 = 6$	& $I_6 \rightarrow 8.33x.09 = 0.75$	& $I_6 \rightarrow 9.1x10=91$
$V_7 \rightarrow 17.5x.4 = 7$	& $I_7 \rightarrow 0.9 + 3.89x.09 = 1.25$	& $I_7 \rightarrow 100+4x10=140$
$V_8 \rightarrow 20x.4 = 8$	& $I_8 \rightarrow 0.9+9.44x.09=1.75$	& $I_8 \rightarrow 100+9x10=190$
$V_9 \rightarrow 22.5x.4 = 9$	& $I_9 \rightarrow 1.8+5x.09 = 2.25$	& $I_9 \rightarrow 200+3.9x10=239$
$V_{10} \rightarrow 25x.4 = 10$	& $I_{10} \rightarrow 2.7+.56x.09=2.75$	& $I_{10} \rightarrow 200+9x10=290$

Evaluation

Finding:

Forward resistance r_f ,

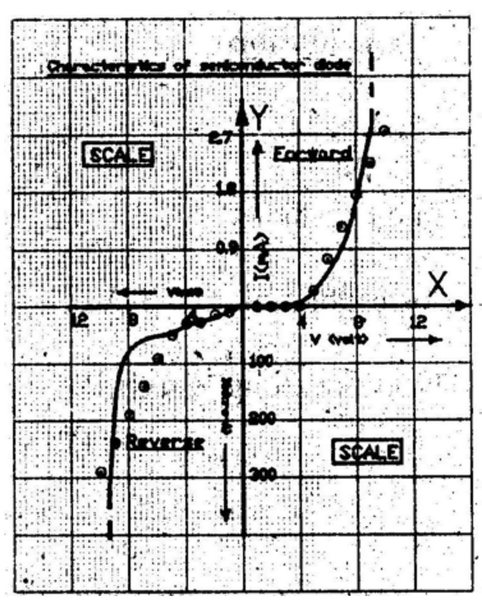
$$r_f = \frac{\Delta V}{\Delta I} = \frac{9\text{volts}}{2.25\text{mA}} = \frac{9}{.0023}$$

$$= 4\ K\Omega$$

Reverse resistance, r_v ,

$$r_v = \frac{\Delta V}{\Delta I} = \frac{9\text{volts}}{239\mu A} = \frac{9}{.000239}$$

$$= 0.04 \text{ mega ohms}$$



In the graph, what conclusion you make from the decreasing curve?

Output Characteristics of Transistor

For I_B = 10 μA

V_{CE} (volts)	0	2	4	5	10	15
I_C (mA)	0	1	1	1	1	1

For I_B = 20 μA

V_{CE} (volts)	0	2	4	5	10	15
I_C (mA)	0	2	2	2.1	2.2	2.5

For I_B = 50 μA

V_{CE} (volts)	0	0.5	1	5	10	15
I_C (mA)	0	5	5	5	5.5	6.5

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 3 volts
Along Y-axis:
1 big div = 1 mA

Step 1: taking V_{CE} along X-axis & I_C along Y-axis

Step 2:

$V_{CE} \rightarrow \frac{15-0}{6} = 2.5 \cong 3 \Rightarrow$ B.d = 3 & s.d = 0.3

$I_C \rightarrow \frac{6.5-0}{8} = 0.813 \cong 1 \Rightarrow$ B.d. = 1 & s.d. = 0.1

Step 4:

For I_B = 10 μA

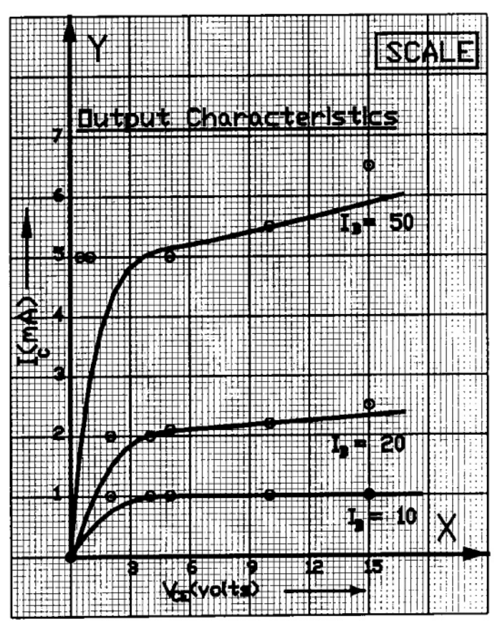
$V_{CE\,1} \rightarrow 0$ & $I_{C\,1} \rightarrow 0$
$V_{CE\,2} \rightarrow 6.6x.3=2$ & $I_{C\,2} \rightarrow 1$
$V_{CE\,3} \rightarrow 3+3.3x.3= 4$ & $I_{C\,3} \rightarrow 1$
$V_{CE\,4} \rightarrow 3+6.6x.3= 5$ & $I_{C\,4} \rightarrow 1$
$V_{CE\,5} \rightarrow 9+3.3x.3= 10$ & $I_{C\,5} \rightarrow 1$
$V_{CE\,6} \rightarrow 15$ & $I_{C\,6} \rightarrow 1$

For I_B = 20 μA

$V_{CE\,1} \rightarrow 0$ & $I_{C\,1} \rightarrow 0$
$V_{CE\,2} \rightarrow 6.6x.3=2$ & $I_{C\,2} \rightarrow 2$
$V_{CE\,3} \rightarrow 3+3.3x.3= 4$ & $I_{C\,3} \rightarrow 2$
$V_{CE\,4} \rightarrow 3+6.6x.3= 5$ & $I_{C\,4} \rightarrow 2.1$
$V_{CE\,5} \rightarrow 9+3.3x.3= 10$ & $I_{C\,5} \rightarrow 2.2$
$V_{CE\,6} \rightarrow 15$ & $I_{C\,6} \rightarrow 2.5$

For I_B = 50 μA

$V_{CE\,1} \rightarrow 0$ & $I_{C\,1} \rightarrow 0$
$V_{CE\,2} \rightarrow 1.6x.3=0.5$ & $I_{C\,2} \rightarrow 5$
$V_{CE\,3} \rightarrow 3.3x.3= 4$ & $I_{C\,3} \rightarrow 5$
$V_{CE\,4} \rightarrow 3+6.6x.3=5$ & $I_{C\,4} \rightarrow 5$
$V_{CE\,5} \rightarrow 9+3.3x.3=10$ & $I_{C\,5} \rightarrow 5.5$
$V_{CE\,6} \rightarrow 15$ & $I_{C\,6} \rightarrow 6.5$



Evaluation

Finding: Output resistance r_c of the collector circuit,

for I = 50 μ A

$$r_c = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{15\text{volts}}{6.5\text{mA}} = \frac{15}{.0065}$$

$$= 2.3\ K\Omega$$

Your calculations and result should be better than this.

Input Characteristics of Transistor

For V_{CE} = 0 volts

V_{BE} (volts)	0	0.3	0.4	0.5	0.6	0.7
I_B (μA)	0	0	25	150	225	280

For V_{CE} = 3 volts

V_{BE} (volts)	0	0.3	0.4	0.6	0.8	1
I_B (μA)	0	0	5	42	100	250

For V_{CE} = 6 volts

V_{BE} (volts)	0	0.3	0.4	0.6	0.8	1
I_B (μA)	0	0	2	50	95	200

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 0.2 volts
Along Y-axis:
1 big div = 50 μA

Step 1: taking V_{BE} along X-axis & I_B along Y-axis

Step 2:

$V_{CE} \rightarrow \frac{1-0}{6} = 0.167 \cong 0.2 \Rightarrow$ B.d =0.2 & s.d = 0.02

$I_C \rightarrow \frac{280-0}{8} = 35 \cong 50 \Rightarrow$ B.d. = 50 & s.d. = 5

Step 4:

For V_{CE} = 0 volts

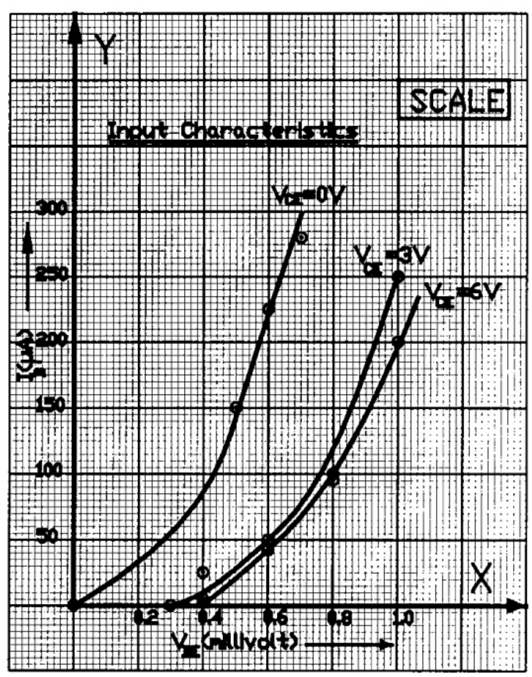
$V_{BE\ 1} \rightarrow 0$ & $I_{B\ 1} \rightarrow 0$
$V_{BE\ 2} \rightarrow .2+.5x.2=.3$ & $I_{B\ 2} \rightarrow 0$
$V_{BE\ 3} \rightarrow 0.4$ & $I_{B\ 3} \rightarrow 5x5=25$
$V_{BE\ 4} \rightarrow .4+.5x.2=.5$ & $I_{B\ 4} \rightarrow 150$
$V_{BE\ 5} \rightarrow 0.6$ & $I_{B\ 5} \rightarrow 200+5x5=225$
$V_{BE\ 6} \rightarrow .6+.5x.2=.7$ & $I_{B\ 6} \rightarrow 250+6x5=280$

For V_{CE} = 3 volts

$V_{BE\ 1} \rightarrow 0$ & $I_{B\ 1} \rightarrow 0$
$V_{BE\ 2} \rightarrow 2+.5x.2=.3$ & $I_{B\ 2} \rightarrow 0$
$V_{BE\ 3} \rightarrow 0.4$ & $I_{B\ 3} \rightarrow 1x5=5$
$V_{BE\ 4} \rightarrow 0.6$ & $I_{B\ 4} \rightarrow 8.4x5=42$
$V_{BE\ 5} \rightarrow 0.8$ & $I_{B\ 5} \rightarrow 100$
$V_{BE\ 6} \rightarrow 1$ & $I_{B\ 6} \rightarrow 250$

For V_{CE} = 6 volts

$V_{BE\ 1} \rightarrow 0$ & $I_{B\ 1} \rightarrow 0$
$V_{BE\ 2} \rightarrow .2+.5x.2=.3$ & $I_{B\ 2} \rightarrow 0$
$V_{BE\ 3} \rightarrow 0.4$ & $I_{B\ 3} \rightarrow .4x5=2$
$V_{BE\ 4} \rightarrow 0.6$ & $I_{B\ 4} \rightarrow 50$
$V_{BE\ 5} \rightarrow 0.8$ & $I_{B\ 5} \rightarrow 50+9x5=95$
$V_{BE\ 6} \rightarrow 1$ & $I_{B\ 6} \rightarrow 200$



Evaluation

Finding:
Input resistance r_i
for V_{CE} = 3 volts

$$r_i = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{1\text{volt}}{250\mu A} = \frac{1}{250x10^{-6}}$$

$= 4\ K\Omega$

Phonautograph is a device for recording visual traces of speech sound.

G.M. Counter Characteristics

V (volts)	375	385	395	410	430	450	470	490	510	520
N(counts)	6	7	8	9	10	10	10	12	13	14

(Read method for plotting a graph on page 7)

Step 1: taking V along X-axis & N along Y-axis

Scale:
Along X-axis:
1 big div = 40 volts
Along Y-axis:
1 big div = 3 counts

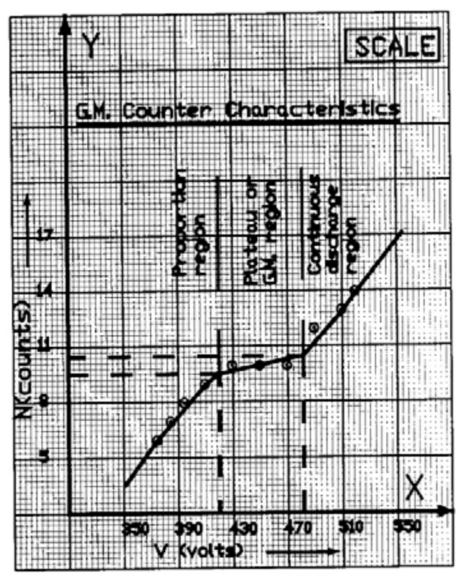
Step 2:

$V \rightarrow \frac{520 - 375}{6} = 24.17 \cong 40 \Rightarrow$ B.d =40 & s.d = 4

$N \rightarrow \frac{14 - 6}{8} = 1 \cong 3 \Rightarrow$ B.d. = 3 & s.d. = 0.3

Step 4:

$V_1 \rightarrow 350 + 6.3x4 = 375$ & $N_1 \rightarrow 5+3.3x.3=6$
$V_2 \rightarrow 350 + 8.7x4 = 385$ & $N_2 \rightarrow 5+6.6x.3= 7$
$V_3 \rightarrow 390 + 1.2x4 = 395$ & $N_3 \rightarrow 8$
$V_4 \rightarrow 390 + 5x4 = 410$ & $N_4 \rightarrow 8+3.3x.3= 9$
$V_5 \rightarrow 430$ & $N_5 \rightarrow 8+6.6x.3= 10$
$V_6 \rightarrow 430 + 5x4 = 450$ & $N_6 \rightarrow 8+6.6x.3= 10$
$V_7 \rightarrow 470$ & $N_7 \rightarrow 8+6.6x.3= 10$
$V_8 \rightarrow 470 + 5x4 = 490$ & $N_8 \rightarrow 11+3.3x.3= 12$
$V_9 \rightarrow 510$ & $N_9 \rightarrow 11+6.6x.3= 13$
$V_{10} \rightarrow 510 + 2.5x4 = 520$ & $N_{10} \rightarrow 14$



Evaluation

Finding:

Slope percentage per volt:

$$= \frac{482 - 421}{10.4 - 9.5} \times \frac{100}{(9.5+10.4)/2}$$

$= 0.15\ \%$

We define x-intercept of a curve is the x-coordinate of the point of intersection of the curve with the x-axis. Similarly y-intercept is defined.

High resistance by Neon flash lamp

T (sec)	0.3675	0.6975	1.115	2.36
R (MΩ)	1	3	5	10

(Read method for plotting a graph on page 7)

Step 1: taking T along X-axis & R along Y-axis

Step 2:

$T \rightarrow \frac{2.36 - 0.37}{6} = 0.33 \cong 0.5 \Rightarrow$ B.d = 0.5 & s.d = 0.05

$R \rightarrow \frac{10 - 1}{8} = 1.125 \cong 1.5 \Rightarrow$ B.d. = 1.5 & s.d. = 0.15

Scale:
Along X-axis:
1 big div = 0.5 sec
Along Y-axis:
1 big div =1.5 MΩ

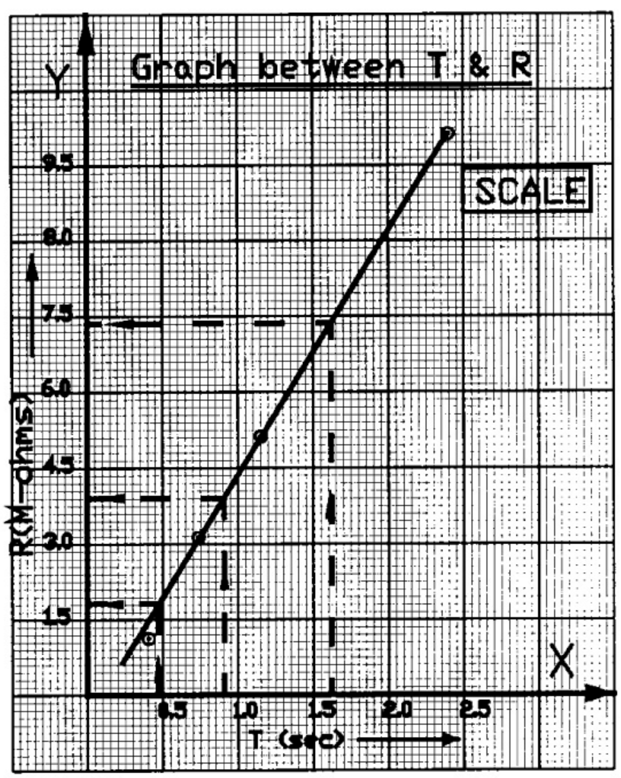
Step 4:

$T_1 \rightarrow 7.3 \text{ x } .05 = 0.3675$ & $R_1 \rightarrow 6.6 \text{ x } .15 = 1$

$T_2 \rightarrow .5 + 3.9 \text{ x } .05 = 0.6975$ & $R_2 \rightarrow 3$

$T_3 \rightarrow 1 + 2.3 \text{ x } .05 = 1.115$ & $R_3 \rightarrow 4.5 + 3.3 \text{ x } .15 = 5$

$T_4 \rightarrow 2 + 7.2 \text{ x } .05 = 2.36$ & $R_4 \rightarrow 9.5 + 3.3 \text{ x } .15 = 10$



Evaluation

Finding:

Values of unknown resistances:

R_1 = 1.8 M Ω

R_2 = 3.9 MΩ

R_3 = 7.4 M Ω

Feldman is admired for his innovation in graphic scoring, using visual symbols for musical sound verses time duration.

$1/d^2$ verses θ for photocell

$1/d^2$ (cm^{-2})	$156x10^{-6}$	$177x10^{-6}$	$204x10^{-6}$	$236x10^{-6}$	$277x10^{-6}$	$330x10^{-6}$	$400x10^{-6}$	$493x10^{-6}$
θ (μA)	25	27.5	30	32.5	40	47.5	55	62.5

(Read method for plotting a graph on page 7)

Scale:
Along X-axis:
1 big div = 70 cm^{-2}
Along Y-axis:
1 big div = 7 μA

Step 1: taking $1/d^2$ along X-axis & θ along Y-axis

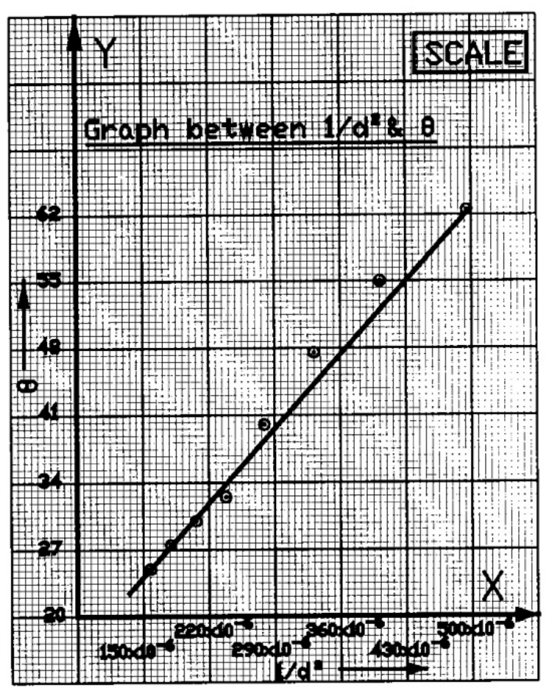
Step 2:

$1/d^2 \rightarrow \frac{493 - 156}{6} = 56.17 \cong 70 \Rightarrow$ B.d = 70 & s.d = 7

$\theta \rightarrow \frac{62.5 - 25}{8} = 4.69 \cong 7 \Rightarrow$ B.d. = 7 & s.d. = 0.7

Step 4:

$1/d^2_1 \rightarrow 150 + .86x7 = 156\ [x10^{-6}]$ & $\theta_1 \rightarrow 20 + 7.1x.7 = 25$
$1/d^2_2 \rightarrow 150 + 3.9x7 = 177[x10^{-6}]$ & $\theta_2 \rightarrow 27 + .7x.7 = 27.5$
$1/d^2_3 \rightarrow 150 + 7.7x7 = 204\ [x10^{-6}]$ & $\theta_3 \rightarrow 27 + 4.3x.7 = 30$
$1/d^2_4 \rightarrow 220 + 2.3x7 = 236\ [x10^{-6}]$ & $\theta_4 \rightarrow 27 + 7.9x.7 = 32.5$
$1/d^2_5 \rightarrow 220 + 8.1x7 = 277\ [x10^{-6}]$ & $\theta_5 \rightarrow 34 + 8.6x.7 = 40$
$1/d^2_6 \rightarrow 290 + 5.7x7 = 330\ [x10^{-6}]$ & $\theta_6 \rightarrow 41 + 9.3x.7 = 47.5$
$1/d^2_7 \rightarrow 360 + 5.7x7 = 400\ [x10^{-6}]$ & $\theta_7 \rightarrow 55$
$1/d^2_8 \rightarrow 430 + 9 x 7 = 493\ [x10^{-6}]$ & $\theta_8 \rightarrow 62 + .7x.7 = 62.5$



Evaluation

Finding:

The slope from graph,

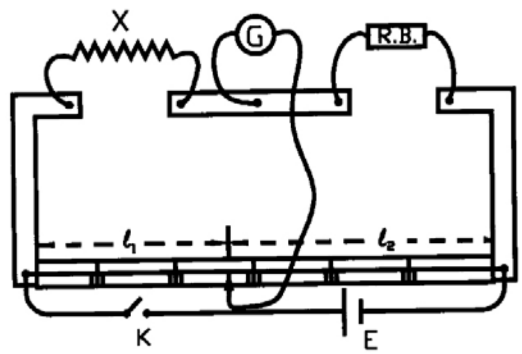
$$\tan\theta = \frac{\Delta\theta}{\Delta\frac{1}{d^2}} = \frac{62.5 - 25}{(493 - 156)x10^{-6}}$$

$$= 0.11 \text{ x } 10^6 \text{ A cm}^2$$

In the graph, what conclusion you make from the increasing curve?

Date………..

Expt: Slide wire bridge



Observations and Calculations:

Least count of the screw gauge = 1/100 mm = 0.01 mm = 0.001 cm

Diameter of the given wire:

i) ----- cm ii) ----- cm iii) ----- cm

Mean diameter = d = ----- cm

Radius of the wire = d/2 = r = ----- cm

Length of the wire = l = ----- cm

No. of obs	Resistance taken out R	AB = l_1	BC = l_2 = 100 - l_1	X = R x $\frac{l_1}{l_2}$
	ohms	cm	cm	ohms
1	9	45.7	54.3	10.6

Mean resistance X = _____ohms

Specific resistance = $\frac{X}{l} \times \pi r^2$ = ______ohm-cm = ______ ohm-m

Actual value (for Nichrome) = 1.1×10^{-6} ohm-m

Percentage error = _____ %

Man is a tool-using animal. –Thomas Carlyle

Home Project:

Make a model analogous to the conduction of electrons in a metal. In the figure, a steel ball rolling down a pegboard incline. Over a long time interval, the motion is characterized by a constant drift velocity down the board.

Experiment No. 1:

To find the resistance of a wire by slide wire bridge**.**

Apparatus:

Slide wire bridge, resistance wire, battery, galvanometer, resistance box, jockey, connecting wires, sand paper, rheostat, screw gauge, meter rod.

Theoretical Base:

From the principle of Wheatstone Bridge, ordinary electrical resistances are most accurately measured by a method of comparison. According to this principle, P / Q = X / R or X = (P/Q) R ohms. Since resistance is directly proportional to length, so the resistances P & Q are replaced by lengths l_1 and l_2 of the wire BC. So X = (l_1 / l_2) R ohms.

Procedure:

1) *Draw the circuit diagram. Arrange all the components.*
2) *Make all the connections except the battery.*
3) *Call your instructor or the teacher to check the connections, then attach battery.*
4) *Check the connections by taking out resistance (say 5 ohms) from resistance box. Insert the key. Touch the jockey turn by turn on both sides of the wire. If the deflection in Galvanometer is opposite to that in first case then the connections are correct.*
5) *Just touch the jockey in the middle of the wire. Adjust the resistance R from resistance box, so the galvanometer shows no deflection when jockey is placed nearly in the middle.*
6) *Repeat twice with small change in the value of R.*
7) *Complete the table. Calculate the resistance from the formula.*

Precautions:

1. Connections must be tight and clean.
2. Connections must be made with the keys open. Insert key for readings.
3. The jockey should not be rubbed along the wire.

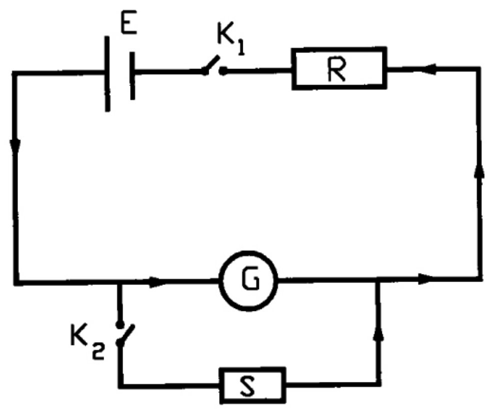
Viva Voce:

Q.1 *Why the null point is sought at the middle of the wire?*
Ans. Because at this part the arrangement becomes very sensitive.
Q.2 *What is the effect of temperature on resistance?*
Ans. It increases as the temperature increases.
Q.3 *On which principle slide wire bridge circuit works?*
Ans. On the principle of Wheatstone bridge.

Date…………

Expt: Half deflection method.

Circuit diagram :



Observations and Calculations:

No. of obs.	Resistance R	Deflection θ	Shunt resistance S	Half deflection θ / 2	R - S	R x S	G = $\frac{R \times S}{R - S}$
	ohms	div.	ohms	div.	ohm	ohm^2	ohms
1	4800	30	99	15			101.08
2							
3							

Mean value of galvanometer resistance = G = ______ ohms

The aim of science is always to reduce complexity to simplicity.
–William James

Home Project:
Solder two wires to each of four flashlight bulbs. Connect them in the various combinations (in parallel & in series) across a 1.5 V battery. Explain the ways the bulbs glow in each case.

Experiment No. 2:

To find the resistance of a Galvanometer by half deflection method.

Apparatus:

Galvanometer, cell, high resistance box, two plug keys, low resistance box, connecting wires, sand paper.

Theoretical Base:

In the figure, when K_1 is closed and K_2 is open. The current through galvanometer shows deflection θ,

$$I_g = \frac{E}{R + G} = k\theta \qquad \ldots\ (1)$$

[$G = R_g$ = galvanometer resistance]

When both keys are closed and S adjusted to reduce deflection to one half, and applying Kirchhoff's 2nd rule on loop including G & S,

$$I_g G - (i - I_g) S = 0 \quad \Rightarrow \quad I_g = i \times S / (G + S)$$

Looking up in fig. (d), the above equation gives,

$$I_g = \frac{E}{R + (G S / G + S)} \times \frac{S}{G + S} = \frac{k\theta}{2} \qquad \ldots\ (2)$$

From eqs (1) & (2), we have

$$\frac{E S}{R (G + S) + G S} = \frac{E}{2(R + G)} \quad \Rightarrow \quad G = \frac{RS}{R - S}$$

If the value of R is large compared to S, i.e., R >> S,

$$\text{then} \quad \frac{R}{R - S} = 1 \quad \Rightarrow \quad G = S$$

Procedure:

1) *Make connections according to the circuit diagram with keys K_1 and K_2 open.*
2) *Check your connections with your teacher.*
3) *Take out high resistance (say 4000 ohms). Close Key K_1, and K_2 being open. Adjust the large deflection (20 to 30) with some more resistances. Note readings.*
4) *Keeping R unchanged close K_2 to see null point of the galvanometer. From shunt resistance take out so much resistances so as the deflection become half of previous one. Note the readings.*
5) *Repeat twice by changing resistance R. Find mean value G.*

Precautions:

1. Key K_1 should be closed only after taking some high resistance.
2. The deflection should be in even number of scale.
3. Zero error of the galvanometer should either be removed or accounted for.

Viva Voce:

Q.1 *What is meant by shunt?*

Ans. A wire or any conductor connected across a galvanometer.

Q.2 *The resistance of which part of galvanometer is measured?*

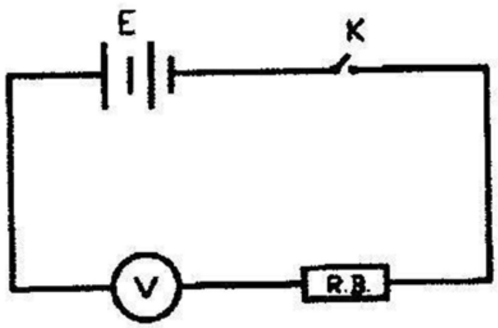
Ans. Of the coil of the galvanometer.

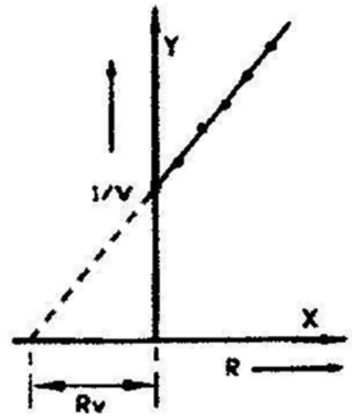
Q.3 *Why galvanometer shows half deflection when both keys are closed?*

Ans. Because half of current goes through shunt and half through galvanometer.

Date…………

Expt: Voltmeter resistance.





Observations and Calculations:

No. of obs.	Resistance R	Voltmeter V	1 / V
	ohms	volts	volts $^{-1}$
1			
2			
3	1000	1.1	0.90
4			
5			
6			

From the graph : The intercept on X-axis = resistance of the voltmeter

R_V = …… ohms

By different methods different men excel
But where is he who can do all things well? –Charles Churchill

Home Project:

Determining voltmeter sensitivity, or the resistance per volt of a voltmeter.

First find full scale deflection current, I_{FSD} , and then sensitivity = 1volt / I_{FSD} = ……. Ω /volts

Also total voltmeter resistance is determined by multiplying the sensitivity (ohms per volt) by the voltmeter range:

R_V = (sensitivity x range)

Experiment No. 3:

To find resistance of a voltmeter by drawing graph between R and 1/V.

Apparatus:

Voltmeter, battery, resistance box, rheostat, key, connecting wires.

Theoretical Base:

In the fig. on the left page, the current passing in the circuit is,

$$I = \frac{E}{R + R_v}$$

And the potential applied E, from Kirchhoff's voltage rule is,

$$E = V + IR = V + \left(\frac{E}{R + R_v}\right) R$$

or $$V = E - \frac{E R}{R + R_v} = E\left(1 - \frac{R}{R + R_v}\right) \quad \text{or} \quad V = \frac{E R_v}{R + R_v}.$$

or $$\frac{1}{V} = \frac{R + R_v}{E R_v} \quad \text{or} \quad R + R_v = E R_v \left(\frac{1}{V}\right)$$

Since E & R_v are constant, $R \propto 1/V$

Also when $1/V = 0$, then $R + R_v = 0$ or $R_v = -R$

The intercept on the X-axis gives the resistance of the voltmeter.

Procedure:

1) *Make a circuit diagram and connect the circuit with key open.*
2) *The emf of the battery should be checked. It should be at least to the maximum voltmeter reading.*
3) *Insert key K and take out some resistance R from resistance box. Note reading.*
4) *Take out the resistance in regular steps and note down the voltmeter reading.*
5) *Complete the table. Plot a graph between R and 1 / V.*
6) *Produce the straight line of the graph backwards to cut at B. The intercept on X-axis gives the resistance of the voltmeter.*

Precautions:

1. Battery should provide a voltage equal to the maximum voltmeter reading.
2. High resistance voltmeter should be used.
3. Resistance should be increased in regular steps.

Viva Voce:

Q. 1: *What is a voltmeter ?*

Ans. It is an instrument for measuring potential difference.

Q. 2: *Why a high resistance voltmeter is preferred here ?*

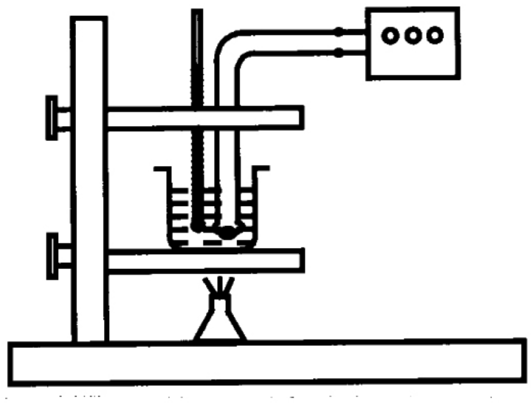
Ans. Because it draws maximum current from the circuit.

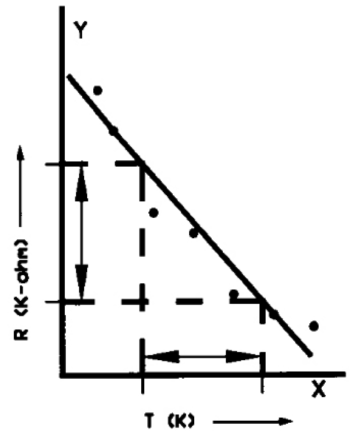
Q. 3: *What is shunt?*

Ans. It is a low resistance placed in parallel to the circuit.

Date…………

Expt: Thermister resistance.





Observations and Calculations:

No. of obs.	Temperature	Absolute temperature	Resistance R
	^{o}C	K	K Ω
1			
2			
3			
4	40	313	2.05
5			
6			
7			

From the graph:

The slope $\Delta R / \Delta T$ = _____ ohm K^{-1}

In science, read by preference, the newest works, in literature, the oldest.
–Edward Bulwer-Lytton

Home Project:

Take off the insulation of a discarded lamp cord several inches. Cut off a piece of one strand 2 inches long. Using a pair of pliers, connect this across the dry cell. Be careful not to burn yourself. The heat produce will make it melt. A fine piece of iron wire will glow like the filament of an electric lamp, but due to oxygen in the air, it will soon burn up.

Experiment No. 4:

Variation of resistance of thermister with temperature.

Apparatus:

Thermister unit, iron stand, multimeter (ohms range), beaker, spirit lamp, thermometer.

Theoretical Base:

A thermister is a temperature sensitive semi-conductor device. The word thermister is derived from ‘thermal resistor’. Usually its resistance decreases considerably with rise in temperature. This high sensitivity to temperature variations makes the thermister good for precise temperature measurements. Depending upon their composition the thermister can have either a positive temperature coefficient (i.e., ‘the fractional change in the resistance of a thermister per degree centigrade rise in temperature’) or a negative temperature coefficient.

Procedure:

1) *Set up the apparatus as shown in the diagram.*
2) *Set the multimeter to appropriate ohms range. Fill the water in the beaker. Fix thermister a little above base of beaker and thermometer at a readable position.*
3) *Note the temperature on thermometer and the resistance in the multimeter. Record the readings in the table.*
4) *Start heating the beaker very slowly. Stir the water in the beaker with a stirrer. [Or pour boiling water into the beaker containing cold water—quick method!]*
5) *Note temperature and the corresponding resistance at regular intervals of 5^o .*
6) *Complete all the columns of the table.*
7) *Plot graph between resistance of thermister and the absolute temperature. The curve is not a straight line. Find the slope of this curve.*

Precautions:

1. Thermister leads must be fixed away from the flame.
2. Thermometer bulb should not touch the walls and the bottom of the beaker.
3. Do not make adjustments to apparatus when it is hot.

Viva Voce:

Q.1 *What is a thermister?*

Ans. A thermister is heat sensitive semi-conductor device. Its resistance decreases when its temperature increases.

Q.2 *What do you mean by temperature coefficient of resistance?*

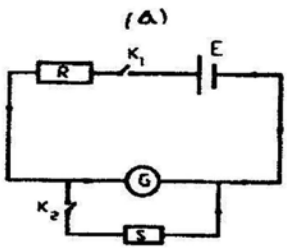
Ans. The fractional change in resistance per Kelvin.

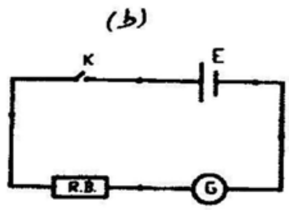
Q.3 *Can a thermister have positive temperature coefficient?*

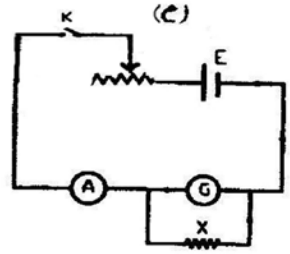
Ans. Yes, thermisters with positive temperature coefficient are also available.

Date…………

Expt: Conversion into ammeter.







Observations and Calculations:

Step 1: Resistance of G by half deflection method.

No. of obs.	Resistance R	Deflection θ	Shunt resistance S	Half deflection θ / 2	G = $\frac{R \times S}{R - S}$
	ohms	div.	ohms	div.	ohms
1	4800	30	99	15	101.08
2					
3					

Mean = G = ohms

Step 2: Current for full scale deflection
EMF of cell = E = ----- volts
Total no. of div. of G = n = ----- divs.
Current for θ div = E / R+G; Current for 1 div.
= (E / R+G) x 1/ θ
Current for full scale deflection = I_g
= (E / R+G) x n / θ = -----A

Step 3: Shunt resistance and length of shunt wire
Range of ammeter = I = 0.2 A

Value of shunt resistance = R_S = X = $\frac{G\ I_g}{I - I_g}$ = ----- ohms

Least count of screw gauge = ----- mm; Zero correction = --- mm
Observed diameter of shunt wire = i) ----- mm, ii) ----- mm, 3) ----- mm
Mean diameter = ----- mm; Corrected diameter = d = ----- mm
Radius of the shunt wire = r = d / 2 = ----- mm = ----- cm
Specific resistance of the wire = ρ = ----- Ω-cm
Length of wire used as shunt = $l = \frac{X \pi r^2}{\rho}$ = ----- cm

Step 4 : Verification

No. of obs.	Galvanometer reading: Deflection θ'	Galvanometer reading: Current in Amp. $(0.1 / n)\ \theta'$	Ammeter reading	Difference
	division	A	A	A
1	10	0.03	0.04	0.01
2				
3				
4				
5				

Give us the tools, and we will finish the job. –Sir Winston Churchill

Home Project:
Make an electromagnet by winding many loops of insulated copper wire on a large nail. Wrap a few layers of paper around the nail before you begin winding. Power it with a flashlight battery. If you do not want the battery to run down too quickly, place a flashlight bulb in series with the battery and coil. Observe its magnetic properties.

Experiment No. 5:

Conversion of galvanometer into ammeter reading up to 0.1 amperes.

Apparatus:

Galvanometer, ammeter, voltmeter, high resistance box, fractional resistance box, two keys, screw gauge, connecting wires.

Theoretical Base:

In the figure, according to Ohm's law,

$$V = I_g R_g \qquad \ldots\ldots (1)$$

and $$V = (I - I_g) R_s \qquad \ldots\ldots (2)$$

From eqs. (1) & (2) we get

$$I_g R_g = (I - I_g) R_s$$

or $$R_s = \frac{I_g}{I - I_g} R_g$$

Where = R_s = X = shunt resistance & R_g = G = galvanometer resistance

Taking length of wire equivalent to X,

$$R_s = X = \rho \frac{l}{A} \quad \text{or} \quad l = X \frac{A}{\rho} = X \frac{\pi r^2}{\rho}$$

Procedure:

1) *Make connections as shown in fig. (a) and determine* ***galvanometer resistance*** *by half deflection method. [see expt. No. 2]*
2) *To find* ***figure of merit****, determine emf of a cell.*
3) *Make connections as shown in fig. (b), and adjust resistance from resistance box for large scale deflection, and complete the table 2.*
4) *Fill the lines below the table 2, and calculate* ***wire length for shunt****.*
5) *For* ***verification****, take calculated length of wire, and make connection as in fig. (c).*
6) *Complete the table 3, by adjusting the resistance from rheostat for maximum deflection in the galvanometer to read the desired reading (0.1 A) in the ammeter.*

Precautions:

1. The cell used should have a constant emf.
2. The wire used for shunt should be of convenient length.
3. Large scale deflection should be used for checking conversion of galvanometer.

Viva Voce:

Q.1 *What is a shunt?*

Ans. Small resistance placed parallel to a circuit, called shunt or shunt resistance.

Q.2 *What is an ammeter?*

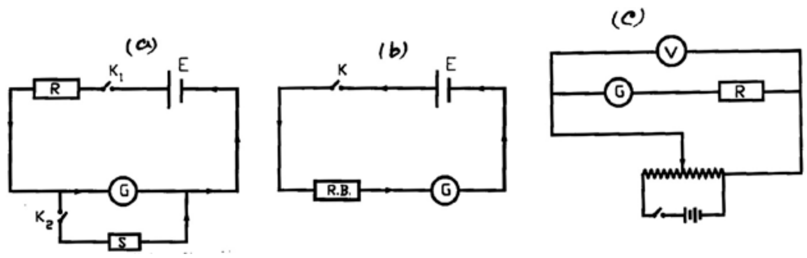
Ans. Device to measure current; it's a low resistance moving coil galvanometer.

Q.3 *How can a galvanometer be converted into an ammeter?*

Ans. By connecting a suitable low resistance in parallel with galvanometer coil.

Date…………

Exp: Conversion into voltmeter.



Observations and Calculations:

Step 1: Resistance of G by half deflection method.

No. of obs.	Resistance R	Deflection θ	Shunt resistance S	Half deflection $\theta / 2$	$G = \frac{R \times S}{R - S}$
	ohms	div.	ohms	div.	ohms
1	4800	30	99	15	101.08
2					
3					

Mean = G = ohms

Step 2: Current for full scale deflection
EMF of cell = E = ----- volts
Total no. of div. of G = n = ----- divs.
Current for θ div = E / R+G; Current for 1 div. = (E / R+G) x 1/ θ
Current for full scale deflection = I_g = (E / R+G) x n / θ = ----- A

Step 3: High resistance connected in series with Galvanometer
Range of voltmeter = V = 3 volts
External resistance to be placed in series with galvanometer = $R_h = \frac{V}{I_g} - G$ = ----- ohms

Step 4: Verification
Each scale division on the converted galvanometer = 3 / n = ----- volts

No. of obs.	Galvanometer reading		Voltmeter reading	Difference
	Deflection θ'	P.D. in volts (2/n) θ'		
	small div.	volts	volts	volts
1				
2	15	1.0	1.0	0
3				

No man's knowledge here can go beyond his experience. –*John Locke*

Home Project:
Make the coil by winding several hundred turns of fine insulated copper wire around a bundle of nails. Connect the coil and a dry cell in series. Hold the ends of the circuit, one in each hand. Touch the two ends together. A current will flow in the coil. With the two ends still in your hands break the circuit. You will feel a slight electric shock. It is due to the induced emf of self-inductance when the circuit was opened.

Experiment No. 6:

Conversion of galvanometer into voltmeter reading up to 3 volts.

Apparatus:

Galvanometer, voltmeter, high resistance box, fractional resistance box, two keys, connecting wires.

Theoretical Base:

To convert a galvanometer into voltmeter reading up to V volts, we have to introduce a resistance R in series with it coil, so that when a potential difference of V volts is applied to its terminals full scale deflection current (I_g) passes through it. In the figure, according to Ohm's law,

$$I_g = \frac{V}{R_x + G} \quad \text{or} \quad R_x = \frac{V}{I_g} \; G$$

An equivalent resistance is placed in series with the galvanometer coil and the readings checked with a standard voltmeter.

Procedure:

1) *Determine the galvanometer resistance G by half deflection method and figure of merit as done in the last experiment.*
2) *Find the current for full-scale deflection* $I_g = nk$.
3) *Fill up the lines above the table and find the value of* ***external resistance***.
4) *Make connections as shown in the fig. (c).*
5) *Fill up the table for* ***verification***.

Precautions:

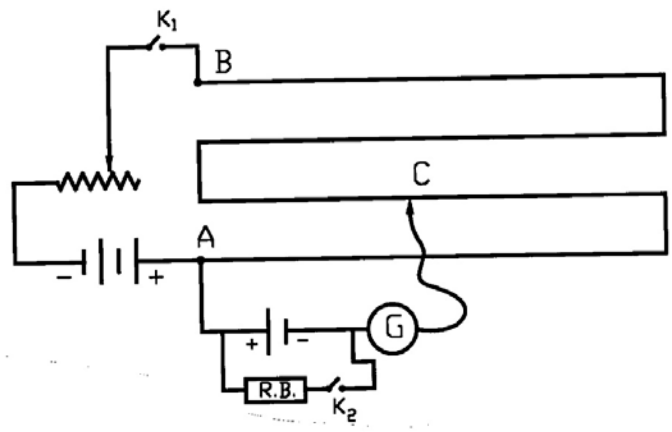
1. Suitable resistances should be removed from the resistance box to produce large deflections in both the instruments.
2. Red marked terminal of voltmeter is always positive, it should be connected to the positive of the battery.
3. The emf of the battery should be greater than the conversion range of the galvanometer.

Viva Voce:

Q.1 *How will you connect a voltmeter in a circuit?*
Ans. It is always connected in parallel with the circuit.
Q.2 *How does a voltmeter differ from an ammeter?*
Ans. A voltmeter is high resistance galvanometer, used for measuring potential difference,; ammeter is a low resistance galvanometer used to measure current.
Q.3 *Why should a voltmeter have very high resistance?*
Ans. It is connected in parallel to the circuit for measuring potential difference. Using high resistance in voltmeter would help not to change P.D. in the circuit.

Date…………

Expt: Internal resistance of a cell.



Observations and Calculations:

No. of obs.	Resistance R	Balancing length l_1	Balancing length l_2	Internal resistance $r = \frac{(l_1 - l_2)}{l_2} R$
	ohms		cm	ohms
1	5		318	0.63
2				
3				

Mean r = _____ ohms

Those who believe that they are exclusively in the right are generally those who achieve something. –*Aldous Huxley*

Home Project:
Take an old dry cell and tear it apart. Examine the zinc container, probably largely eaten away. After it there is a blotting paper. Then there is a paste of ammonium chloride and manganese dioxide and finally there will be a carbon rod. You will find some zinc chloride (dry white substance) left on the zinc.
Make a wet cell by punching holes in the zinc of an old dry cell and placing the cell in a jar containing salt solution.

Experiment No. 7:

To find the internal resistance of a cell using a Potentiometer.

Apparatus:

Potentiometer, cell, battery, two keys, rheostat, galvanometer, resistance box, connecting wires.

Theoretical Base:

When a cell is supplying a current I to an external circuit having resistance R, it is always accompanied by the flow of the same current I inside the cell. This current inside the cell comes across a resistance due to electrolyte present in the cell. This resistance is called internal resistance r of the cell.
Under the condition the potential difference e (= IR) between the terminals of the cell is less than emf E and the difference (E - e) represents the potential difference required to drive the current I through the internal resistance r.

$$\text{So} \quad E - e = I\,r \quad \text{or} \quad r = \frac{E - e}{I}$$

$$\text{or} \quad r = \left(\frac{E - e}{e}\right) R \quad \text{or} \quad r = \left(\frac{E}{e} - 1\right) R \qquad \left[\text{as } I = \frac{e}{R}\right]$$

The lengths l_1 and l_2 correspond to E and e respectively, so

$$R = \left(\frac{l_1}{l_2} - 1\right)R \quad \text{or} \quad r = \left(\frac{l_1 - l_2}{l_2}\right) R$$

Procedure:

1) *Arrange and connect the circuit as shown in the diagram.*
2) *Check the connections from your teacher before adding battery.*
3) *Close the key K_1 . keeping key K_2 open, adjust the rheostat. Find the balance point C_1 on the potentiometer wire.. Measure this length l_1 from the point A. Leave the rheostat at this position for rest of the experiment. .*
4) *Take out a resistance R from the resistance box and close key K_2 . Obtain new balance point C_2 on the potentiometer wire. Measure l_2 from point A.*
5) *Take different values of R and calculate internal resistance of the cell.*

Precautions:

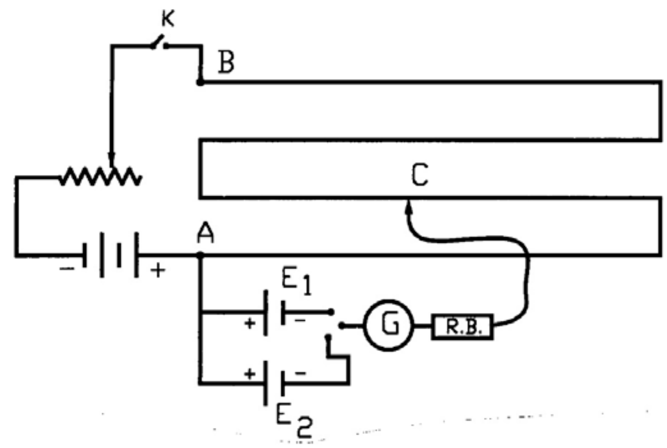
1. When determining l_1 , key K_2 must be open.
2. Allow the current to flow only at the time of observations.
3. The rheostat should be so adjusted as to get the null points at large lengths.

Viva Voce:

Q.1 *What do you mean by internal resistance of a cell?*
Ans. The resistance offered by electrolyte to passage of current.
Q.2 *What is potentiometer?*
Ans. It is an apparatus for comparing and measuring potentials.
Q.3 *Whether internal resistance remains constant or not?*
Ans. It does not remain constant but changes when current drawn.

Date…………

Expt: emf of a cell by potentiometer.



Observations and Calculations:

o. of obs.	Balancing length with cell $E_1 = l_1$	Balancing length with cell $E_2 = l_2$	$E_2 = E_1 \times l_2 / l_1$
	(cm)	(cm)	volts
1	284	298	1.33
2			
3			

Mean emf of cell E_2 = ______ volts

Energy is Eternal Delight. –*William Blake*

Home Project:

Take 6V or 12V battery. Connect wires to its two terminals. How close together can the tips of the two wires be brought before a spark jumps? Why the sparking distance is so small? What can you conclude about long sparks?

Experiment No. 8:

To determine the emf of a cell using a Potentiometer.

Apparatus:

Potentiometer, battery, two cells, galvanometer, voltmeter, rheostat, jockey, sand paper, connecting wires, three way key, plug key.

Theoretical Base:

Let emf of the cell be E_1 with l_1 the corresponding length, and emf of unknown cell be E_2 with the corresponding length l_2 . Since the potentiometer wire is uniform, the length is directly proportional to the potential difference.

So $$\frac{E_2}{E_1} = \frac{l_2}{l_1} \quad \text{or} \quad E_2 = E_1 \times \frac{l_2}{l_1}$$

Procedure:

1) *Check the emf of the battery and cells using a voltmeter.*
2) *Make connections according to the circuit diagram. Positive terminals of the battery and cells should be connected to a common terminal A. Negative terminals of the cells should be connected with two way key.*
3) *First key K is closed and plug 1 is put in two way key. Now cell E_1 is in circuit. Touch the jockey at both ends A & B, the opposite deflection in the galvanometer will certify correct connections. Now locate balance point between the end A and B. When jockey is at balance point, the deflection of galvanometer is zero.*
4) *Measure l_1 from the end A. Now take out plug 1 and put in plug 2 in two-way key. Find balance point. Measure l_2 from A.*
5) *Repeat the experiment twice by changing rheostat resistance.*
6) *Complete all the columns of the table and the lines above and below the table. Find mean emf of the given cell E_2 .*

Precautions:

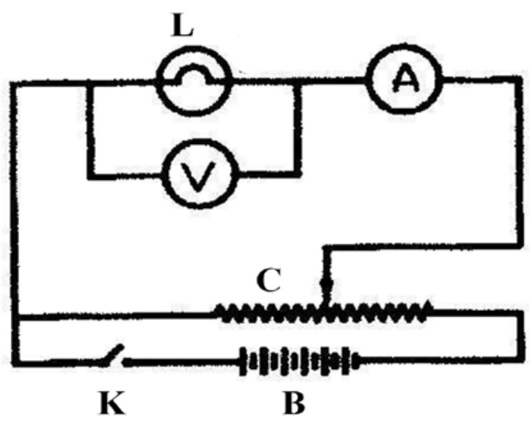
1. The emf of the battery should be higher than each of the cells.
2. Do not drag jockey on the potentiometer wire while locating balance point.
3. Current should be passed for a very short interval of time.

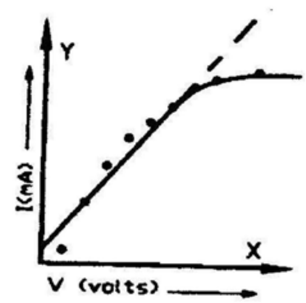
Viva Voce:

Q.1 *What is emf of a cell?*
Ans. The potential difference between its terminals for open circuit.
Q.2 *Why the deflection of galvanometer is zero at balance point?*
Ans. Because emf of the cell is equal to potential drop here.
Q.3 *Which type of galvanometer is suitable in potentiometer circuit?*
Ans. A sensitive center-point galvanometer is most suitable.

Date…………

Expt: Tungsten filament.





Observation and Calculations:

No. of obs.	Voltmeter reading V	Ammeter reading I	R = V/I
	volts	mA	ohms
1			
2			
3	0.4	0.32	1.2
4			
5			
6			

Result : As the graph is not a straight line. So it is non-ohmic resistance.

All things flow; nothing abide. –*Plato*

Home Project:

Take dry cell and a flashlight bulb. Connect them with a finest iron wire. The lamp will light, but not as bright as when you connect a copper wire. By varying the length of the iron wire, you can observe that the resistance depends on its length. By using heavier wire, you can see that resistance depends inversely on the size of the wire.

Experiment No. 9:

Relation between current passing through a tungsten filament lamp and the potential applied across it.

Apparatus:

6 volt battery, bulb (6V, 0.5A), voltmeter, high resistance rheostat, ammeter, connecting wires.

Theoretical Base:

According to Ohm's law, 'the magnitude of the current in metals is proportional to the applied voltage as long as the temperature of the conductor is kept the same'. So the resistance of conductor can be calculated by **R = V / I.** In case of tungsten filament lamp, the Ohm's law is not valid because as the amount of current passing through filament increases, the temperature of filament is also increases. And the resistance of the filament changes. The graph between V and I is straight line in the start but becomes a curve in the end. It shows that the resistance of filament remains constant in the beginning but increases at the end. So that Ohm's law is not valid in this case.

Procedure:

1) *Make the connections according to the circuit diagram. Rheostat and ammeter is connected in series but voltmeter in parallel with the bulb. .*
2) *Apply a small voltage by adjusting the sliding contact, so the ammeter and voltmeter give small initial readings. Note these readings.*
3) *Take the readings of ammeter and voltmeter in regular steps by changing the resistance of rheostat.*
4) *Complete the table . Plot a graph between V and I, which is not a straight line.*

Precautions:

1. High resistance rheostat should be used.
2. Voltmeter and ammeter must be connected with right polarity as in figure.
3. Voltage should be varied in small steps.

Viva Voce:

Q.1 *Why Tungsten filament becomes white hot with passage of current through it?*

Ans. Due to its high resistance, heat is generated by the passage of current in it.

Q.2 *Why bulbs are connected in parallel with power points?*

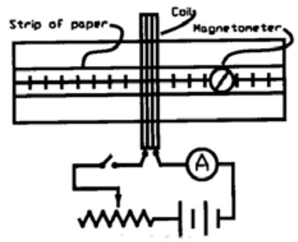
Ans. To keep the voltage same across each of the bulb.

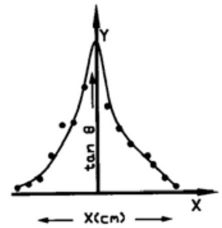
Q.3 *Why a Tungsten filament of a bulb does not obey Ohm's law?*

Ans. As the temperature of filament changes and for Ohm's law, temperature must remain constant.

Date…………

Expt: Variation of magnetic field.





Observation and Calculations:

Number of turns in the coil = n = _____

Diameter of the coil, D = ____ cm. & radius, r = ____ cm = _____ m

Current through the coil = I = 0.8 amp

Deflection = θ = 80^o ; $\mu_o = 1.257 \times 10^{-6}$ Weber/amp

Magnetic field at the center = B = $\frac{\mu_o n I}{D}$ = 4.57×10^{-4} Tesla

No. of obs.	Distance from the center, x (cm)	Distance from the center, x (m)	Deflection of the magnetometer: Direct θ	Reverse current θ'	$180 - \theta' = \theta$	Mean θ	Tan θ	$\tan\theta(r^2 + x^2)^{3/2}$
1	14	0.14	20	170	180 –170 = 10	15	0.2679	9.12×10^{-6}
2	12							
3	10							
4	8							
5	6							
6	4							
7	2							
8	0	0	80	102	180 –102 = 78	79	5.1446	8.56×10^{-6}
9	-2							
10	-4							
11	-6							
12	-8							
13	-10	-0.10	20	140	180 –140 = 40	30	0.5774	8.58×10^{-6}
14	-12							
15	-14							

Mean value of $\tan\theta(r^2 + x^2)^{3/2}$ = _____ $\times 10^{-6}$

Truth lies within a little and certain compass, but error is immense –H. Bolingbroke

Home Project1:

Make simple compass needle by stroking long needle lengthwise with the pole of a strong magnet. To assemble a compass, glue the needle to a small block of wood and float it in a dish of water.

Home Project2:

Iron objects distort the earth's magnetic field. Use a compass to discover how the direction of the earth's field is changed by different metal objects in your home.

Experiment No. 10:

Variation of magnetic field along the axis of a circular coil.

Apparatus:

Circular coil fitted on wooden board, ammeter, rheostat, magnetometer.

Theoretical Base:

From the application of Ampere's Law, field due to a current in a circular coil is : $B = \frac{\mu_o n I}{2r} = \frac{\mu_o n I}{D}$ or $B = H \tan\theta = \frac{\mu_o n I}{D}$ or $H = \frac{\mu_o n I}{\tan\theta\, D}$

where H = horizontal component of the earth's magnetic field

μ_o = permeability of free space = $4\pi \times 10^{-7}$ Wb A^{-1} m^{-1}

n = No. of turns; I = current passing (in amperes) ; D = 2 r

and if this field is made to act at right angles on a freely suspended magnetic needle, the needle will undergo a deflection θ.

The field at any point *x* on its central axis is given by :

$$B = \frac{\mu_o n I r^2}{2 (r^2 + x^2)^{3/2}} \text{ or } B = H \tan\theta = \frac{\mu_o n I r^2}{2 (r^2 + x^2)^{3/2}}$$

$$\text{or} \quad 2 (r^2 + x^2)^{3/2} \tan\theta = \frac{\mu_o n I r^2}{H}$$

For a given coil and current, n r^2 and I are constant, so

$$2 (r^2 + x^2)^{3/2} \tan\theta = \text{constant}$$

Procedure:

1) *Place a magnetometer at the center of the coil. Adjust the board so that the plane of the coil is in North-South direction.*
2) *Put 30 cm long strip of paper along the axis of the coil (East –West direction) .*
3) *Turn the circuit on. Adjust the current for magnetometer deflection of 70^o or 80^o .*
4) *Fill up the table and the lines above it.*
5) *Plot graph between distance x verses tan θ.*

Precautions:

1. Keep current through the coil constant.
2. Do not place magnets or iron pieces near the apparatus.
3. Plane of the coil should be exactly coincident with the magnetic meridian.

Viva Voce:

Q.1 *What is the nature of the field due to current alone?*

Ans. Field due to current alone will be represented by circular lines of force.

Q.2 *Is any practical application of using uniform field at the center of a coil?*

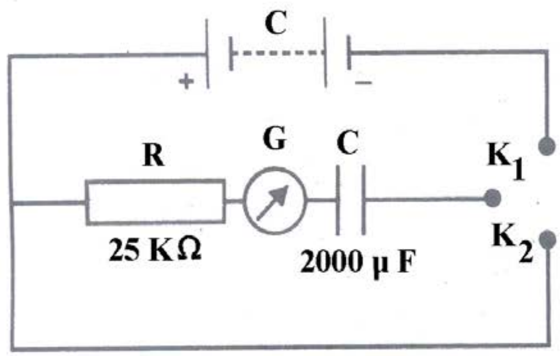
Ans. It is used in the construction of a tangent galvanometer.

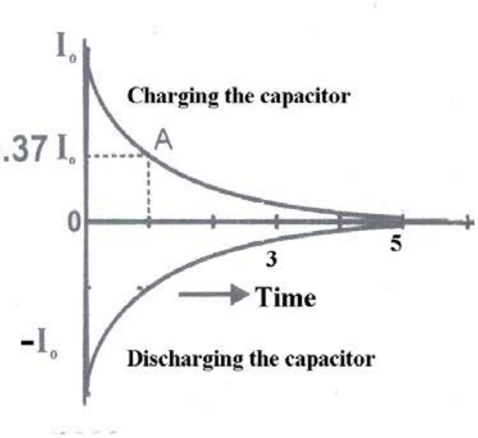
Q.3 *Give an approximate value of the strength of Earth's magnetic field.*

Ans. Earth's magnetic field is about 50 micro-tesla.

Date:…………….

Expt: Charging & discharging of a capacitor.





Observations & Calculations:

Value of resistor used = R = ____ KΩ
Value of the capacitor used = C = ____ μF

For charging current			For discharging current		
No. of obs.	time sec	voltage volts	No. of obs.	time sec	voltage volts
1					
2					
3					
4	18	12	4	9	2.5
5					
6					

From the graph, time constant = _____ sec
Theoretical value of time constant = R x C = ____ sec
Difference = _______ sec.

Activity is the only road to knowledge. –George Bernard Shaw

Home Project:
Determining half life $T_{1/2}$, which is the time needed to drop to 50% of the initial value.
Thus $I = ½\ I_o = I_o\ e^{-T_{1/2}/RC}$.
Taking natural logarithm and rearranging,
we find: $T_{1/2} = RC\ ln2 = 0.693\ \tau$

Experiment No. 11:

Charging and discharging of a capacitor and to measure time constant.

Apparatus:

Capacitor (1000 μF), resistor (10KΩ), voltmeter, power supply (12 VDC), stop watch, two-way key, connecting wires.

Theoretical Base:

A capacitor stores charge. When C is in series with an external resistance R, it forms an RC circuit. The time constant of an RC circuit is, '*the time during which the charging current falls to 37% of initial maximum current*'.
Mathematically, $I = I_o e^{-\tau / RC}$ or $V = V_o e^{-\tau / RC}$.
After one time constant, $t = \tau = RC$, so

$$V = V_o e^{-RC / RC} = V_o \; e^{-1} = V_o / e = V_o / 2.718 = 0.37V_o$$

Procedure:

1) *Set up the apparatus as shown in the figure. Keep the power supply off till you start taking the readings.*
2) *Close key K of position 1 so that the capacitor is completely discharged and the ammeter shows zero reading.*
3) *Turn power supply on. Shift key K to position 2 and simultaneously start stop watch. Note first reading at zero time corresponding to max. charging current. Take further readings after every 15 seconds. Stop taking observations when the current falls to 20 % of the initial current. Allow the capacitor to be charged further till the deflection of the ammeter becomes almost zero..*
4) *Reset the stop watch to zero reading. Shift key K to position 2 and simultaneously start the stopwatch. Again take observations of discharging current in the same way as before. Keep on taking these readings till the discharging current falls below 20% of the initial current.*
5) *Plot two graphs for charging and discharging of the capacitor as shown in figure.*
6) *Find time constants, against the voltage* $V = 0.37V_o$ *, and fill up all the lines.*

Precautions:

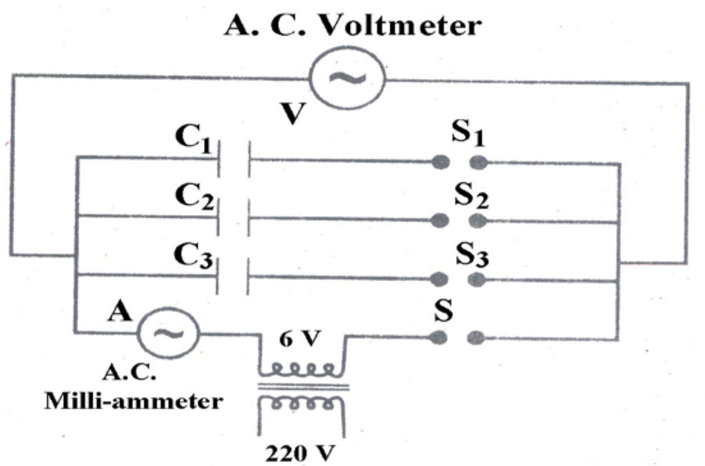
1. As the key is opened, at the same time start the stopwatch should be started.
2. High value capacitor and high value resistance should be used.
3. Discharge capacitor before taking a new set of observation.

Viva Voce:

Q.1 *What is time constant?*
Ans. The time in which a capacitor discharges to 37% of the maximum charge.
Q.2 *Why is the discharging current maximum initially?*
Ans. Because full capacitor voltage is applied across the resistor R.
Q.3 *What type of decrease is that of discharge current?*
Ans. It is the exponential decrease.

Date……………

Expt: Current and capacity relation.



Observations and Calculations:

No. of obs.	Capacity of the capacitor C	Current I	I / C
	μ F	mA	
1	3.3	12	3.63×10^3
2			
3			
4			
5			
6			

Inference: As the ratio I / C is constant, showing the current is directly proportional to the capacity in an A.C. circuit.

The whole of science is nothing more than a refinement of everyday thinking. –*Albert Einstein*

Home Project:

Perform analogous experiment for decay or decreases with time the capacitance of a capacitor.

Start with 50 one-rupee coins, shake and throw them and then select those that come up heads on the first throw. Repeat the process using those that come up heads. Select those that come up heads on the second throw and repeat. Continue till no coin is left. Plot a graph of number of coins verses the trial number, which will be a fair approximation to the decay curve.

Experiment No. 12:

Relation between current and capacitance when different capacitors are used in A.C. circuit.

Apparatus:

A.C. supply, step down transformer, five capacitors, key, A.C. milli-ammeter, flexible wires.

Theoretical Base:

The reactance (X_c)of a capacitance in the A.C. circuit is;

$$X_c = 1 / \omega C \ , \ \omega = 2\pi f$$

$$\text{or } X_c = \frac{1}{2\pi f C}$$

now the current I in a capacitance will be,

$$I = \frac{V}{X_c} = \frac{V}{1 / 2\pi f C} = 2\pi f C V$$

Since $2\pi f V$ = constant, so I = const. x C or $\frac{I}{C}$ = constant

Procedure:

1) *Connect the components as shown in the diagram. The components are in series with the secondary of the transformer.*
2) *Note down the zero correction and least count of milli-ammeter scale.*
3) *Put on the circuit by inserting the plug in the key. Note the reading of milli-ammeter and the capacity of the capacitor. .*
4) *Repeat the experiment with the given different capacitors.*
5) *Plot a graph between current and capacity by taking capacity along X-axis and current along Y-axis.*

Precautions:

1. One should be cautious of touching various parts of the circuit.
2. Use a step-down transformer with an output of 8-12 volts.
3. Do not use electrolytic capacitor. Paper capacitor may be used.

Viva Voce:

Q.1 *What is a capacitor?*

Ans. It is a combination of conducting plates separated by an insulator used to store electric charge.

Q.2 *What is the effect of dielectric in capacitor?*

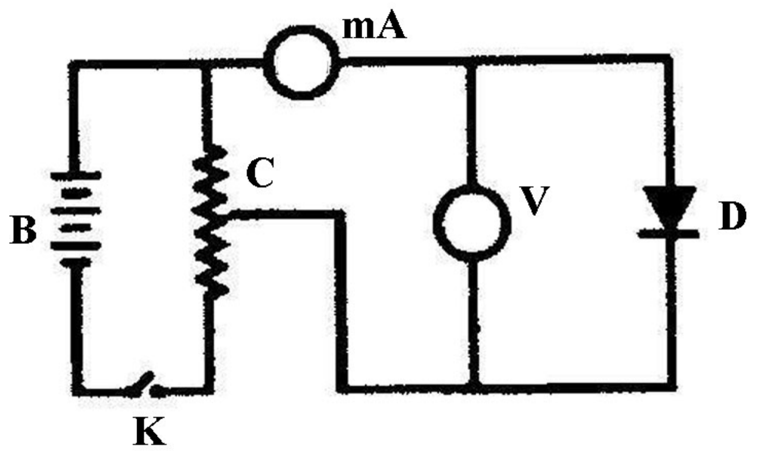
Ans. It increases the capacitance.

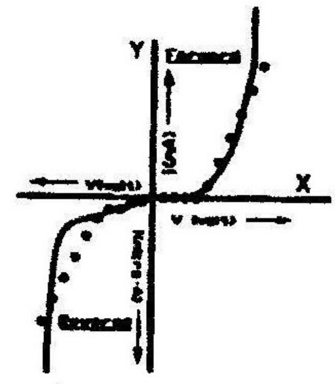
Q.3 *What is the reactance of a capacitor?*

Ans. Reactance of a capacitor is its opposition to alternating current.

Date……………

Expt: Semi-conductor diode.





Observations and Calculations:

Forward characteristics

No. of obs.	Voltmeter reading V	Milliammeter reading I
	volts	mA
1	1	0
2		
3		
4	6	0.75
5		
6		

Reverse characteristics

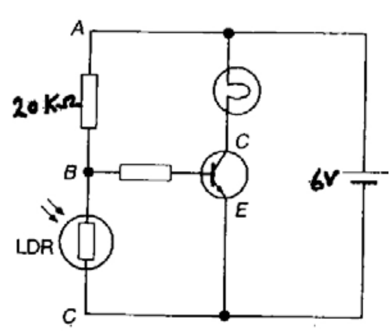
No. of obs.	Voltmeter reading V	Micro-ammeter reading I
	volts	μA
1	1	10
2		
3		
4	7	140
5		
6		

Inference: The shape of the graph between V and I shows that the resulting current increases with the applied voltage upto one volt. At reverse biasing there is less current with the increase of voltage.

The new electronic independence recreates the world in the image of a global village. –*Marshall McLuhan*

Home Project:

Assemble the discrete components as in figure, to turning on a light in the dark. In daylight an LDR resistance is 500 Ω , and in the dark it is 1,000,000 Ω. The voltage across 20kΩ resistor is small compared with voltage across LDR. The transistor is switched on and the lamp lights.



Experiment No. 13:

Characteristics of a semi-conductor diode and calculation of forward and reverse current resistance.

Apparatus:

A semi-conductor diode, milliammeter, voltmeter, rheostat, key, battery, connecting wires.

Theoretical Base:

Semiconductors are not pure materials because small amounts of impurity atoms have been added to them. Their resistivity is intermediate between those of conductors and insulators. A junction between p and n type of materials forms a semiconductor diode. It is unidirectional device in the sense that it allows charge carriers to flow only in one direction. If the positive terminal of a battery is connected with p-type and negative terminal with n-type of diode then the semiconductor diode is called ***forward biased***. If the negative terminal of the battery is connected with p-type and positive terminal with n-type, then the semiconductor diode is called ***reverse biased***. Semiconductors are widely used in circuit elements such as in transistors and other semiconductor devices.

Procedure:

1) *Connect all the components as shown in the circuit diagram. For forward characteristics connect the positive of the diode to the negative of ammeter.*
2) *Plug in the key K_1 and adjust the rheostat so that the voltmeter reads 0.1 volts. Close the key K_2 and take the milliammeter reading.*
3) *Increase the applied voltage in steps of 0.1 volts interval and note both voltmeter and milliammeter readings.*
4) *Reverse the connections of the diode for reverse characteristics. Take the readings as before at least 2 volt interval upto 20 volts.*
5) *Plot a graph by taking voltage along X-axis and current along Y-axis. Use the same graph for forward and reverse characteristics.*

Precautions:

1. The voltage applied should be increased by regular steps.
2. High voltage should be avoided.
3. The end mark with red spot should be treated as cathode.

Viva Voce:

Q.1 *What is a semi-conductor?*

Ans. The substance whose resistance lie in between conductor and insulator.

Q.2 *What is the use of a semi-conductor diode?*

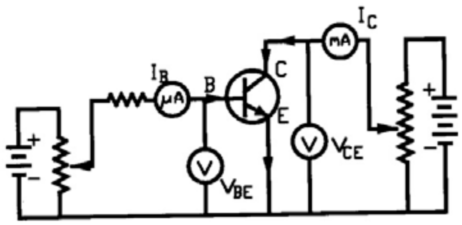
Ans. It is used to convert A.C. into D.C.

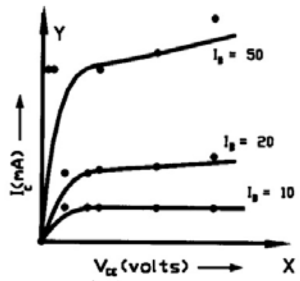
Q.3 *What is a p-n junction?*

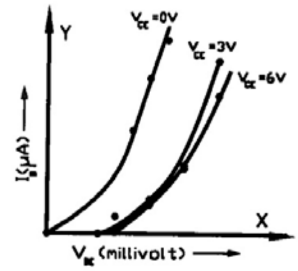
Ans. It is a combination of p and n type substances.

Date……………

Expt: Transistor characteristics.







<u>Observations and Calculations:</u>

For Output Characteristics

No. of obs.	I_B	V_{CE}	I_C
	μA	volts	mA
1			
2			
3	10	4	1
4			
5			
6			
1			
2			
3	20		
4		5	2.1
5			
6			
1			
2			
3	50		
4		5	5
5			
6			

For Input Characteristics

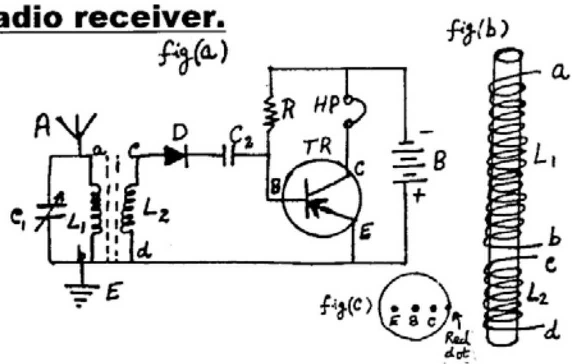
No. of obs.	V_{CE}	V_{BE}	I_B
	volts	milli-volts	μA
1			
2			
3	0	0.4	25
4			
5			
6			
1			
2			
3	3		
4		0.6	42
5			
6			
1			
2			
3	6		
4		0.6	50
5			
6			

Science is nothing but trained and organized common sense.

–Thomas Henry Huxley

<u>Home Project:</u>

Assemble the discrete components as in figure, to <u>make a simple</u> <u>radio receiver.</u>



<u>Details of the figure</u>:

A = Aerial, 50 feet
E = Earth
D = Crystle diode, OA 79
L_1= 60 turns coil of ferrite rod
L_2= 10 " " " " "
C_1= Variable condenser, 365 pF
C_2= Condenser, 5 uF
R = Resistor, 220 K
TR= Transistor, AF 117
HP= Headphone, high impedance
B = Batter, 6 volt.

Experiment No. 14:

Characteristics of a N.P.N. transistor.

Apparatus:

A N.P.N. transistor, voltmeter, millivoltmeter, micro-ammeter, milliammeter, two batteries of 9 volts, a resistor (1 K)

Theoretical Base:

A transistor consists of a single crystal of germanium or silicon, which is grown in such a way that it has three regions. The central region is known as base and the other two regions are called emitter and collector. Usually the base is very thin ~ 10^{-6} m. For normal operation, batteries for emitter-base junction is forward biased and its collector-base junction is reverse biased. In npn transistor *conventional current* I_E flows from base to emitter. Small part of it, current I_B flows in base, the rest of it I_C flows in the collector. The fundamental equation is $I_E = I_C + I_B$. Current gain $\beta = I_C / I_B$, is constant for given transistor. Transistors are basically used as amplifiers in major electronic circuits.

Procedure:

1) *Make connections as shown in the figure.*
2) *Adjust all the components with the help of your teacher according to the desired readings and with proper range and polarity.*
3) *Take the readings first for output characteristics and then for input characteristics by filling the above tables with appropriate ranges.*
4) *Take three sets with I_B at 0, 10 and 20 μA by measuring I_C and V_{CE} for output characteristics.*
5) *Take three sets with V_{CE} at 0, 3 and 6 volts by measuring I_B and V_{BE} for input characteristics.*
6) *Draw the curves between V_{CE} and I_C for each value of I_B and the curves between V_{BE} and I_B for each value of V_{CE} .*

Precautions:

1. Avoid the rough handling of the transistor.
2. Care must be taken in connecting the batteries.
3. Proper biasing of base and collector must be applied.

Viva Voce:

Q.1 *What are the types of transistors?*

Ans. There are two types, i) P.N.P. and ii) N.P.N.

Q.2 *How many PN junctions are there in a transistor?*

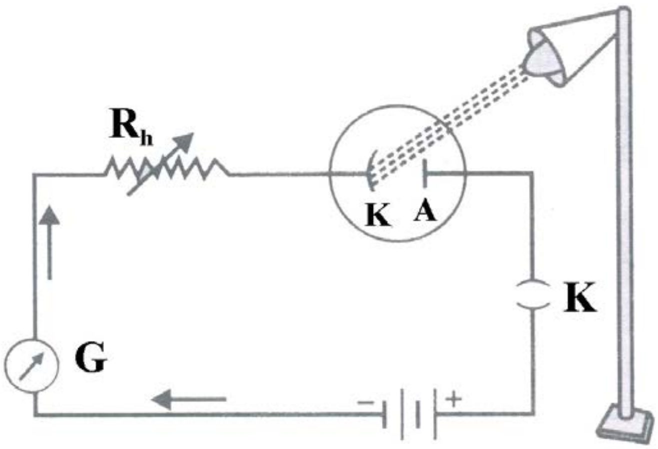
Ans. There are two PN junctions; Emitter-base and Collector-base junction.

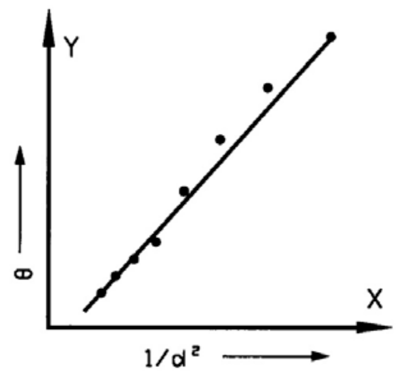
Q.3 *What do you mean by doping?*

Ans. The addition of donor or acceptor atoms (impurity) to a semiconductor.

Date…………

Expt: Photo-cell.





Observations and Calculations:

No. of obs.	Distance of lamp from photo-cell d (cm)	Deflection of galvanometer θ (μA)	($I \propto 1/d^2$) $1/d^2$	θ / d^2
1	80	25	156.25×10^{-6}	39.06×10^{-4}
2				
3				
4				
5				
6				
7				
8				

Inference: As the graph between deflection θ and $1/d^2$ is a straight line, therefore, light intensity from a point source decreases as the inverse square of the distance from the source. This proves the inverse square law.

All human science is but the increment of the power of the eye. –John Fiske

Home Project:
Finding the wavelength at which the maximum radiation occurs, if temperature of a person's skin is 34 °C.
Apply Wien's displacement Law: $\lambda_{max} T = 2.898 \times 10^{-3}$ m.K

Experiment No. 15:

Study of the variation of electric current with intensity of light using a photocell.

Apparatus:

Photo-electric cell, sensitive galvanometer, battery, rheostat, key, electric bulb.

Theoretical Base:

Photocell is a device for converting light energy into electrical energy. It consists of an anode and a photosensitive cathode, from which photoelectrons are emitted when light falls on it. According to inverse square law, 'the intensity of light from a point source varies inversely as the square of the distance from the source, i.e., $I \propto 1 / d^2$. So a graph between photoelectric current or deflection (θ) and $1 / d^2$ will be a straight line.

Procedure:

1) *Arrange the apparatus as shown in the figure. Here all the components are in series. The bulb should be selected and fixed in such a way that its point light falls on the photo-electric cell.*
2) *Put on the lamp. Adjust the suitable deflection in the galvanometer.*
3) *Note the deflection, θ in the galvanometer (or micro-ammeter) and the corresponding distance, d of the photo-cell from the lamp. Change the distance d in regular steps and note the deflection θ in the galvanometer.*
4) *Draw a graph between $1 / d^2$ verses θ. It will be a straight line. .*

Precautions:

1. The voltage of the bulb must remain constant.
2. A point source of light should be used.
3. Start the experiment from maximum distance and decrease to minimum.

Viva Voce:

Q.1 *What is meant by photo-electrons?*

Ans. Electrons emitted from a light-sensitive material when illuminated.

Q.2 *Define photoelectric effect.*

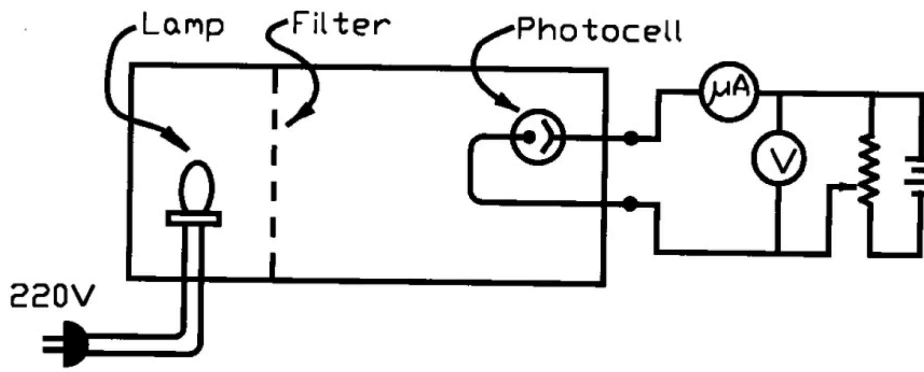
Ans. The emission of electrons by a substance when illuminated by electromagnetic radiation.

Q.3 *What is a photo cell?*

Ans. Photo cell is a device, which convert light energy into electrical energy under certain conditions.

Date………..

Expt: Planck's constant.



Observations and Calculations:

Velocity of light = c = 3×10^{8} m s^{-1}
Charge on an electron = e = 1.6×10^{-19} coulombs

No. of obs.	Filter	Wavelength λ	Current I	Stopping potential V	$h = \frac{e(V_1 - V_2)\lambda_1\lambda_2}{c(\lambda_2 - \lambda_1)}$
	colour	x 10^{-10} m	μA	volts	J-s
1	Red	6843	1.3	0.3	-----
2	Yellow	5835	0.7	0.6	6.338×10^{-34}
3	Green				
4	Violet				

Mean calculated value of h = _____ x 10^{-34} J-s

Standard value of h = 6.626×10^{-34} J-s

A man likes marvelous things, so he invents them, and is astonished.

–Edgar Watson

Home Project:
Find the materials that have responses to different colours of ligfht.
The human eye receives a different colour sensation from green light than it receives from red light. However, lights of different colours reaching a phototube make its cathode produce different amounts of electrons.
Check responses of colours with an LDR.

Experiment No. 16:

To estimate the value of Planck's constant by using photo cell tube and coloured light filters.

Apparatus:

Photocell tube with mercury lamp fitted in a box, micro-ammeter (0-10μA), voltmeter (0-1V), coloured filters, power supply, connecting wires.

Theoretical Base:

From photoelectric effect, the maximum energy of photoelectrons is:

$$\tfrac{1}{2} m v^2_{max} = V_o e \qquad \ldots(1)$$

& Einstein's photoelectric equation is; $h f - \phi = \tfrac{1}{2} m v^2_{max}$ ….. (2)

Equations (1) & (2) gives; $V_o e = h f - \phi$ or $V e = h \nu - \phi$

where $V = V_o$ = stopping potential & $\nu = f$

If two incident light radiations having photon energies $h \nu_1$ & $h \nu_2$ falls on photosensitive surface with stopping potentials V_1 & V_2, then we have

$$V_1 e = h \nu_1 - \phi \quad \& \quad V_2 e = h \nu_2 - \phi \Rightarrow V_1 e - V_2 e = h \nu_1 - h \nu_2$$

$$\text{or} \quad (V_1 - V_2)e = h(\nu_1 - \nu_2) \quad \text{or} \quad h(\nu_1 - \nu_2) = (V_1 - V_2)e$$

$$\text{or} \quad h = \frac{(V_1 - V_2)e}{c/\lambda_1 - c/\lambda_2} = \frac{\lambda_1 \lambda_2 (V_1 - V_2)e}{c(\lambda_2 - \lambda_1)} \qquad [\nu = c/\lambda]$$

Procedure:

1) *Make connections as shown in the figure. Note that the anode of the photocell is connected to negative terminal and cathode to positive terminal of the battery.*
2) *Place one of the colour filter (say red) in the slot provided in the box.*
3) *Before making power supply on, check the all connections thoroughly. Turn on the power supply and the lamp in the phtocell. The voltmeter and micro-ammeter will show the readings.*
4) *Slowly increase power supply voltage. The current in the micro-ammeter decreases. At certain voltage this current becomes zero. Note this value of voltage from the voltmeter, which is stopping potential V_s.*
5) *Complete the table by using all the filters. And the lines below the table.*

Precautions:

1. A mercury light should be preferred to white light for better result.
2. Turn off the light before changing the filter.
3. Measure the stopping potential very carefully.

Viva Voce:

Q.1 *How does stopping potential depend upon the intensity of light?*

Ans. Stopping potential does not depend upon the intensity of light.

Q.2 *What is stopping potential?*

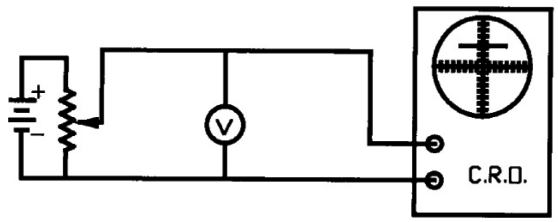
Ans. The reverse potential at which the current becomes zero.

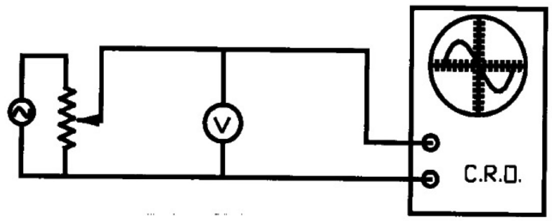
Q.3 *What is Planck's law?*

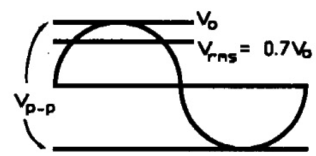
Ans. $E = h f$, which shows that energy & frequency are directly proportional.

Date………..

Expt: Measuring DC/AC by CRO.







Observations and Calculations:

For measurement of D.C. voltage

No. of obs.	Voltage shown by CRO V_R	Multi-meter reading V_m	Difference $(V_R - V_m)$
	div = volts	volts	volts
1	8 div = 6 volts	6.15	0.15
2			
3			

For measurement of A.C. voltage

Calibrating V_{P-P} : Standard A.C. voltage source = V_S = (say) 6.3 volts a.c.
$V_{P-P} = V_S$ x 2 / 0.7 = y div = (say) 12 div = 6.3 x 2 / 0.7 = (say)18 volts
so 1 div. = V_{P-P} / y = 18 / 12 = (say)1.5 volts

No. of obs.	Voltage shown by CRO V_{P-P}	$V_{PP} / 2 = V_o$	$0.7 V_o = V_{rms}$	Multi-meter reading V_m	Difference $(V_{rms} - V_m)$
	div = volts	volts	volts	volts	volts
1	6 div = 9 volts	4.5	3.15	3.2	0.05
2					
3					

Science is nothing but perception. –*Plato*

Student Project:
Connect the cathode-ray oscilloscope with a microphone. If you want to see visible demonstration of vibrations, sing into the microphone. Look the screen and adjust the waveform. Differentiate between noise and singing notes.

Experiment No. 17:

Measurement of D.C. and A.C. voltage by Cathode Ray Oscilloscope.

Apparatus:

Cathode ray oscilloscope, DC power supply(0-30V), AC power supply, high resistance potentiometer, digital multimeter, connecting wires.

Theoretical Base:

Cathode ray oscilloscope is an electronic device used to measure voltages, frequency, short time intervals and to display input signals into waveforms. Its principal component is **cathode ray tube**. The filament is heated by an electric supply. The cathode gets heated and emits electrons. The electrons are accelerated towards anode. The **Y-plates** are used to bend to beam up or down. The **grid** controls the brightness. The **X-plates** are used to move the beam across the screen. The **screen** is coated in a fluorescent material. The beam of electrons finally strikes the screen and shows the **output display**.

Procedure:

1) *Check the cathode ray oscilloscope (CRO). Get used to with functioning of all its knobs. See its display by applying with hands the input signal.*
2) *Adjust the knobs of sweep time per division, vertical gain control and others, so that, to observe a horizontal trace on the oscilloscope screen.*
3) *Calibrate CRO with known voltage source. Set the vertical gain control to (say) 1.5 volts per division. So that trace on the oscilloscope screen rises up by one division from the zero line, i.e., 1.5 volt/div x 1 div = 1.5 volts.*
4) *The voltage to be measured from DC & AC power supplies is applied to the Y plates / input terminal of the CRO.*
5) *After the adjustments, AC and DC signals appear as shown in the figures.*
6) *Measure the voltage given by the power supply with a digital multimeter.*
7) *Fill up all the columns of both the tables.*

Precautions:

1. Handle the oscilloscope carefully and with delicate hands.
2. Do not apply more than 30 volts to input of the CRO.
3. Do not handle the current leads to the supply when it is on.

Viva Voce:

Q.1 *What is cathode ray oscilloscope?*

Ans. A device that enables different electrical signals to be examined visually.

Q.2 *Why is a CRO used to measure voltages?*

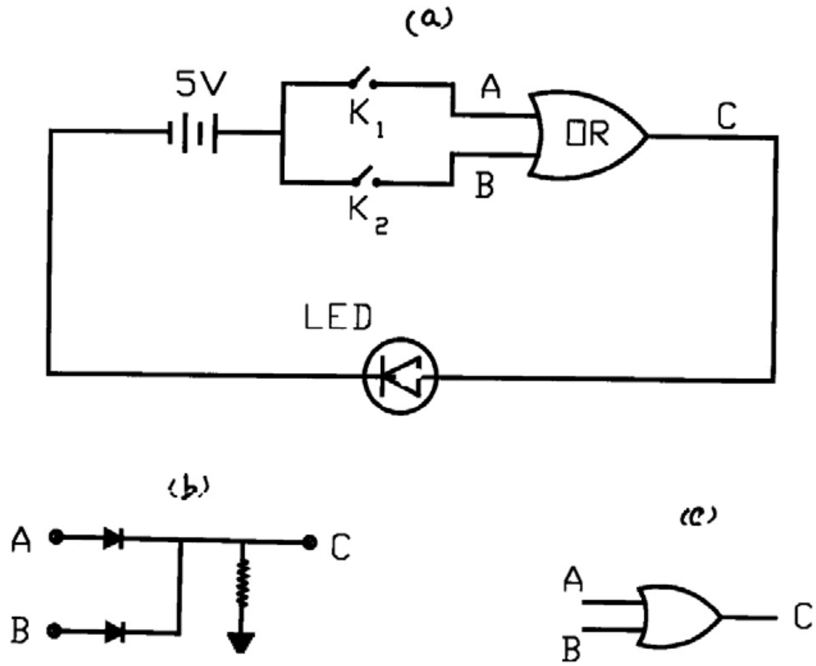
Ans. Because it has an very high resistance and draws no current from a source.

Q.3 *Why is CRO called a visual voltmeter?*

Ans. It is able to show voltage variation with time.

Date…………

Expt: OR gate.



Observations and Calculations:

Truth table for 2 input OR gate:

Inputs		Output
A	B	C
0	0	0
0	1	1
1	1	1
1	0	1

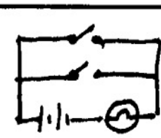
Inference:

In case of OR gate, the output becomes high when any one of inputs is high.

Our art is dazzled blindness before the truth. *–Franz Kafka*

Home Project:

Make the OR gate by taking a 1.5V battery, two switches and a flashlight bulb.



Experiment No. 18(a):

To verify truth table for OR gate.

Apparatus:

OR gate unit, LED indicator module, DC power supply (5-8 volts), keys, connecting wires.

Theoretical Base:

Logic gates are electronic circuits designed to perform logical functions based on Boolean algebra. Normally these circuits operate between two discrete voltage levels, i. e., high and low levels, and described as binary logic.

OR gate is a circuit with two or more inputs and one output whose output is high if any one or more of the inputs are high. The **Truth table** is given on the last page. Its **mathematical notation** is : X = A + B

Procedure:

1) *From the given apparatus, set up the connections as shown in the fig. (a) or for discrete components as shown in fig. (b). .*
2) *The output terminal of OR gate is to be connected with LED indicator and then with the negative terminal of the power supply.*
3) *Here in OR gate; if either input is ON or if both are ON, the output is also ON.*
4) *To verify, keeping both keys K_1 and K_2 OFF, there is not any current at input terminals A and B, i.e., they are both at 0, 0,. So the output terminal C is also OFF, i.e., at 0, so LED indicator is also OFF.*
5) *Close the key K_1 and keeping K_2 OFF. The input terminal A is ON, i.e., at 1 and B is OFF, i.e., at 0, so LED indicator is ON.*
6) *Close K_2 and keeping K_1 OFF. The input terminal A is OFF, i.e., at 0 and B is ON, i.e., at 1. So at output terminal C LED is ON, i.e., at 1.*
7) *Now close both keys K_1 and K_2 , then both input terminal A and B are ON, i.e., at 1, 1. At output terminal C, the LED is ON, i.e., at 1, which verifies the truth table for OR gate.*

Precautions:

1. The ends of the connecting wires should be rubbed with sand paper.
2. The circuit diagram should be correctly drawn.
3. The connections should be neat and clean.

Viva Voce:

Q.1 *What is a logic gate?*

Ans. The electronic circuits which implement various logic operations.

Q.2 *What is the Boolean expression for OR gate?*

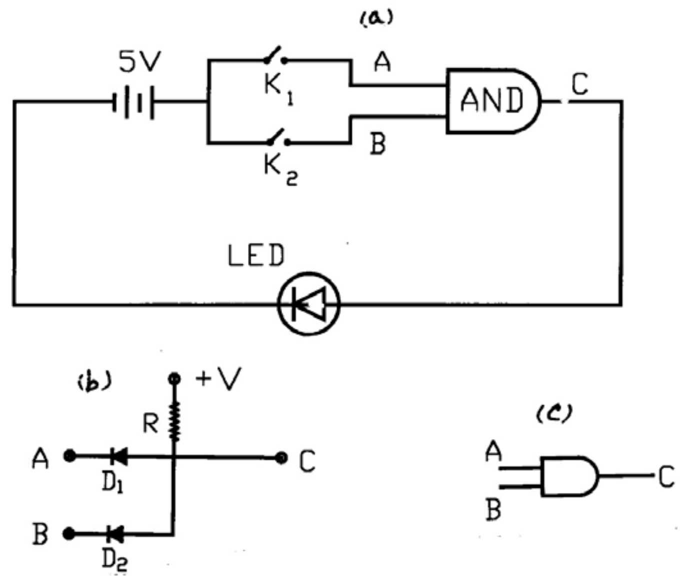
Ans. The Boolean expression for OR gate is A + B.

Q.3 *Can an OR gate perform an AND operation?*

Ans. Yes, if we consider the complementary logic.

Date…………

Expt: AND gate.



Observations and Calculations:

Truth table for 2 input AND gate:

Inputs		Output
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Inference:

In case of AND gate, the output is high only when all the inputs are high.

Truth never hurts the teller. *–Robert Browning*

Home Project:
Look at the electric meter by which the power company monitors your power. Read it each day to obtain a series of values for your daily use of electric energy.

Experiment No. 18(b):

To verify truth table for AND gate.

Apparatus:

AND gate unit, LED indicator module, DC power supply (5-8 volts), keys., connecting wires.

Theoretical Base:

AND gate is a circuit with two or more inputs and one output in which the output signal is high if and only if all the inputs are high simultaneously. That is, AND gate has output 1 when both inputs are 1. It is all-or-nothing gate because an output occurs only when all its inputs are present. Its **Truth table** is given on the last page. The **mathematical notation** is: $X = A \bullet B$.

Procedure:

1) *From the given apparatus, set up the connections as shown in the fig. (a) or for discrete components as shown in fig. (b). .*
2) *The output terminal of AND gate is to be connected with LED indicator and then with the negative terminal of the power supply.*
3) *To verify, keeping both keys K_1 and K_2 OFF, there is not any current at input terminals A and B, i.e., they are both at 0, 0,. So the output terminal C is also OFF, i.e., at 0, so LED indicator is also OFF.*
4) *Close the key K_1 and keeping K_2 OFF. The input terminal A is ON, i.e., at 1 and B is OFF, i.e., at 0. Then the output terminal C is also OFF, i.e., at 0, so LED indicator is OFF.*
5) *Close K_2 and keeping K_1 OFF. The input terminal A is OFF, i.e., at 0 and B is ON, i.e., at 1. So at output terminal C LED is OFF.*
6) *Now close both keys K_1 and K_2 , then both input terminal A and B are ON, i.e., at 1, 1. At output terminal C, the LED is ON, i.e., at 1, which verifies the truth table for AND gate.*

Precautions:

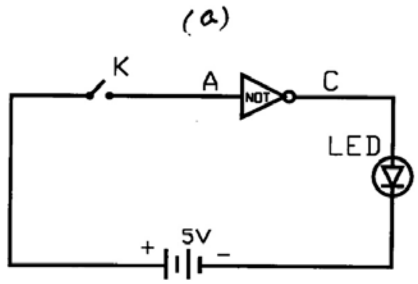
1. The connections should be made according to the circuit diagram.
2. The components should be checked separately, in case of non-verification.
3. Crocodile clips should be preferred with connecting wires.

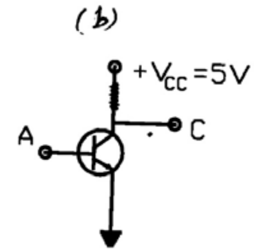
Viva Voce:

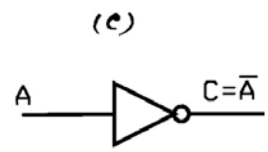
Q.1 *Why is the AND gate termed as an all-or-nothing gate?*
Ans. Because output occurs only when all inputs are high.
Q.2 *Is an AND gate equivalent to a series switching circuit?*
Ans. Yes, a series switching circuit is equivalent to an AND gate.
Q.3 *Can an AND gate be used as an OR gate?*
Ans. An AND gate can be used as OR gate with inputs and output in complement form.

Date…………

Expt: NOT gate.







Observations and Calculations:

Truth table for NOT gate:

Input	Output
A	C
1	0
0	1

Inference:

A NOT gate gives a high output when its inputs is low and vice versa.
Output of NOT is complement of input.

*The real danger is not that computers will begin to think like men,
but that men will begin to think like computers.* –*Sydney J. Harris*

Home Project:
Note down the similarities and differences between electrical conduction and heat conduction. Practically take some iron/copper stick and connect the two ends at different temperatures. And then under certain potential difference.

Experiment No. 18(c):

To verify truth table for NOT gate.

Apparatus:

AND gate unit, LED indicator module, DC power supply (5-8 volts), keys., connecting wires.

Theoretical Base:

NOT gate is a circuit with one input whose output is high if the input is low and vice versa. It is also called an inverter because it inverts the output. In this gate the output is always complement of the input, i.e., if input is 1 or high then output is 0 or low and vice versa. Its **Truth table** is given on the last page. The **mathematical notation** is: X = A.

Procedure:

1) *Take a NOT gate and make connections as shown in the fig. (a) or for discrete components as shown in fig. (b). .*
2) *The output terminal C of NOT gate is connected with LED indicator and then to the negative terminal of the battery.*
3) *The working of NOT gate is that, the output is ON if the input is OFF.*
4) ***To verify it**, put the key K, the input terminal A is ON, i.e., at 1. So the output terminal C is OFF, i.e., at 0 state. So LED remains OFF.*
5) *Now open the key, so input terminal A is OFF, i.e., at 0 state. The output terminal C is ON, i.e., at 1 state, so LED indicator is ON.*
6) *The truth table noted describes all the possible states of the NOT gate.*

Precautions:

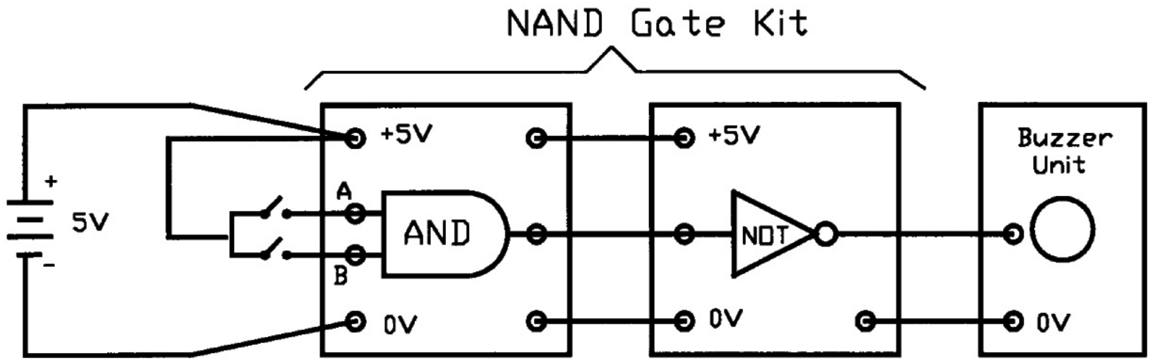
1. Do not use long connecting wires.
2. Do not use A.C. power supply.
3. For good results use logic bread board.

Viva Voce:

Q.1 *What happens when a NOT gate is connected to the output of OR gate?*
Ans. It becomes a NOR gate.
Q.2 *Why is the NOT gate known as an inverter?*
Ans. Because it inverts the input signal, i.e., it reverses the logic state.
Q.3 *What is the only function of a NOT gate?*
Ans. The only function of the NOT gate is to invert the input.

Date…………

Expt: Burglar alarm.



Observations and Calculations:

State — 1 = buzzer On
State — 0 = buzzer Off

Input A	Input B	Output	Buzzer
1	1	0	Off
0	1	1	On
1	0	1	On
0	0	1	On

Inference:

In a NAND gate the burglar alarm is On when any one of its inputs goes low due some interruption which make the circuit break.

O whistle, and I'll come to you, my dear! *–Robert Burns*

Home Project:
Shuffle across a rug so that your body becomes negatively charged. You then reach toward an uncharged doorknob, but a spark jumps between your index finger and the doorknob when they are separated by 0.50 cm. To find the potential difference between your finger and the doorknob:
$\Delta V = Ed$, [$E = 3.0 \times 10^6$ V/m, $d = 5.0 \times 10^{-3}$ m] = ... = 15000 V !!!

Experiment No. 19:

To make burglar alarm using NAND gate.

Apparatus:

NAND gate unit, buzzer, power supply, keys, connecting wires.

Theoretical Base:

The three most fundamental logic gates are; OR, AND, and NOT gates. **NAND gate** is the combination of AND and NOT gate. It is a circuit with two or more inputs and one output, whose output is high if any one or more of the inputs is low, and low if all the inputs are high.

Burglar alarm is **an application** of logic gates. It used to protect buildings, offices and houses from burglars or thieves. It is fitted inside the building or at main gates.

The **Truth table** (NAND gate) is given on the last page. The **mathematical notation** is $X = A \bullet B$

Procedure:

1) *Set up the circuit as shown in the figure. NAND gate is equivalent to an AND gate followed by a NOT gate.*
2) *Close the keys K_1 and K_2 so that both the inputs A and B of AND gate are at high voltage and thus the output is also at high voltage. so input of NOT gate is high and its output is low. The buzzer will not be switched on.*
3) *The keys K and K to be fitted in the doors are the keys to trap the burglar. When any one of these keys is opened due to interruption, output of AND gate becomes low. This causes the output of NOT gate to be high and ultimately the buzzer is switched on.*

Precautions:

1. Connections should be tight and clean.
2. Two way key should be used for current supply in two paths.
3. The power supply should not exceed beyond 8 volts.

Viva Voce:

Q.1 *Why is it called burglar alarm?*

Ans. As it is fitted inside the office buildings & houses to protect from burglars.

Q.2 *What is a trap switch?*

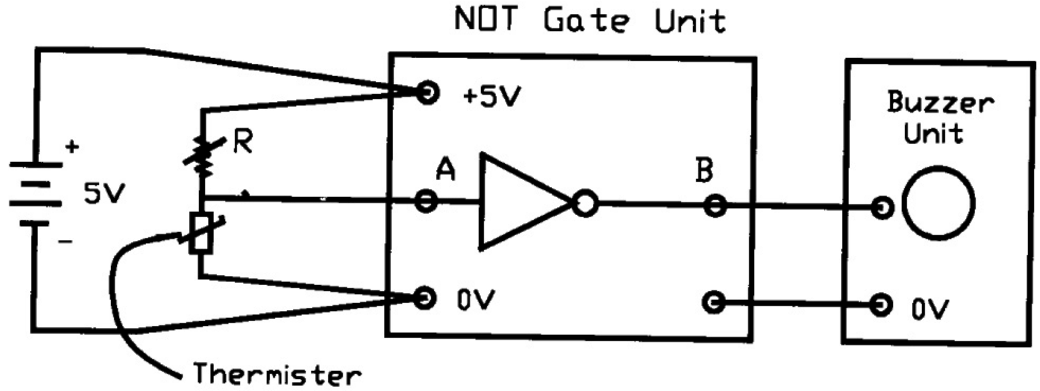
Ans. It is a switch fixed in a door so that when it is opened, the switch opens and changes the state of the input of the system.

Q.3 *What is NAND gate?*

Ans. The NAND gate is, a NOT-AND gate. It operates as an AND followed by a NOT gate.

Date…………

Expt: Fire alarm.



Observations and Calculations:

State — 1 = buzzer On
State — 0 = buzzer Off

Thermister State	Input A	Output B	Buzzer
Hot	1	1	On
Cold	1	0	Off

Inference:

Fire alarm is activated in NOT gate when its input goes low due to circuit break with some interruption. With variable resistor the sensitivity is adjusted.

Your own property is concerned when your neighbor's house is on fire.
–Horace

Home Project1:
Using the smoke from a cigarette, trace air movements in the vicinity of a fireplace, a cold air place, a hot air place, a leaky door or window. Do this preferably on a cold winter.
Home Project2:
Locate the central breaker box in your home. Trip (or switch off) one of the breakers and determine what portion of your home it serves. So check all the breakers and note the portions each of them serve.

Experiment No. 20:

To make a fire alarm using NOT gate.

Apparatus:

NOT gate unit, buzzer unit, thermister unit, power supply, connecting wires, a lamp or burner.

Theoretical Base:

Some detectors are designed to respond to smoke, and others to heat. Detector systems are required in public buildings, apartment houses, and sometimes private homes.

Two major types of smoke detectors are available. One is an ionization device that contains a small radioactive source for ionizing the air molecules between a pair of electrodes, permitting a very small current to flow between the pair. If smoke particles from a fire enter this space, they reduce the flow of current by adhering to the ionized molecules. The drop in current sets off a buzzer or other alarm. The second type of smoke detector uses a photoelectric cell. In some of these detectors smoke that enters obscures a steady beam of light; in others, the smoke scatters a light ray from a diode so that the cell can detect it. In either case the change sets off an alarm.

Procedure:

1) *Set up the circuit as shown in the figure. Adjust the variable resistor in the middle.*
2) *Heat the thermister by moving it quickly over a flame. The buzzer will sound.*
3) *Remove the thermister from heat.*
4) *Adjust the variable resistor to different positions and then repeat step 2 to check the sensitivity of the alarm.*

Precautions:

1. Adjust the variable resistance for maximum sensitivity so that alarm sounds with minimum increase of temperature.
2. Thermister should not be heated excessively.
3. High resistance box should be used for variable resistance.

Viva Voce:

Q.1 *Why is NOT gate called a fire alarm?*

Ans. Because this system operates by heating the thermister with fire or burner.

Q.2 *Why is the NOT gate called an inverter?*

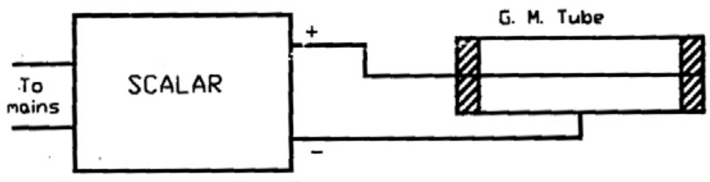
Ans. As its input is 1 when the output is zero and vice versa, the NOT gate is known as inverter.

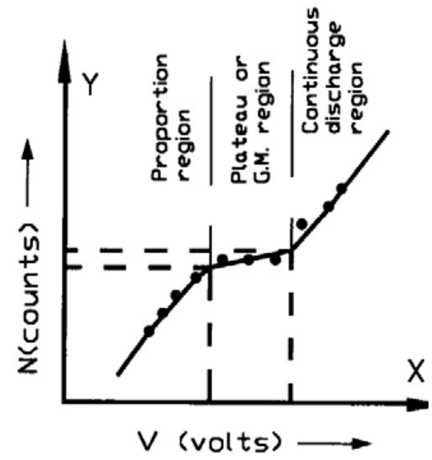
Q.3 *What is the used of fire alarm?*

Ans. It protects the office buildings and houses from danger.

Date…………

Expt: G.M. tube.





Observations and Calculations:

No. of obs.	Voltage applied between electrodes V (volts)	No. of counts N
1	375	6
2		
3		
4		
5		
6		
7		
8		
9		
10		

Value of voltage at the start of plateau $= V_1 =$ _____
Value of voltage at the end of plateau $= V_2 =$ _____
No. of counts at the start of plateau $= N_1 =$ _____
No. of counts at the end of plateau $= N_2 =$ _______

$$\text{Slope percentage per volt} = \frac{N_2 - N_1}{V_2 - V_1} \times \frac{100}{\frac{(N_1 + N_2)}{2}} = \_\_\_\_\_\_ \%$$

Science has nothing to be ashamed of, even in the ruins of Nagasaki.
–Jacob Bronowski

Home Project:
Using G.M. Counter, determine the background radiation from luminous dial watches, clocks and some uranium containing chemical salts(you can borrow from your Chemistry Department).

Experiment No. 21:

Characteristics of a G.M. tube.

Apparatus:

Geiger-Muller tube, scalar or electronic counting device, AC mains.

Theoretical Base:

Geiger-Muller tube is an instrument used for the detection and measurement of radioactivity. It is gas-filled radiation detector operated at high voltage in which the gas amplification effect produces a large discharge pulse after each primary ionizing event.

Here the **principle** of ionization chamber is used. The discharge in the tube results from the ionization produced by the incident radiation.

Its **construction** is simple and is most widely used detector of single particles. It is usually worked with about 400 volts applied between the electrodes.

Its essential parts are; a long glass tube containing two electrodes. Stiff central wire is very thin and is the anode in a hollow metal cylinder acting as a cathode.

Procedure:

1) *Fix up the electronic counting device or scalar with G.M. tube. Connect the scalar with the AC mains.*
2) *Switch on the voltage knob and check the recorder whether it records some reading or not. You will see, it will record no reading for a voltage smaller than the threshold voltage.*
3) *Check the response of G.M. counter with natural background source without using artificial source.*
4) *Go on increasing the voltage by regular intervals and note down the readings of the recorder when it starts recording counts.*
5) *Plot graph between the voltage and the number of counts.*
6) *From the graph, fill up the lines below the table. And work out the slope percentage per volt.*

Precautions:

1. Discharge caused by passage of the particles should not become permanent.
2. A natural background source should be used to study the characteristics.
3. The voltage applied should be changed by regular steps.

Viva Voce:

Q.1 *What is a Geiger-Muller counter?*

Ans. A device used for detection and counting of charged particles.

Q.2 *What is a self quenching counter?*

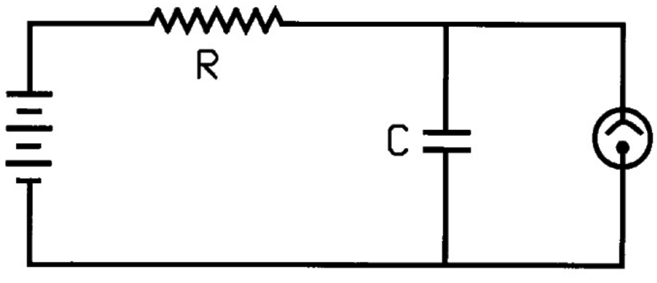
Ans. Having a counter filled with argon and alcohol mixture.

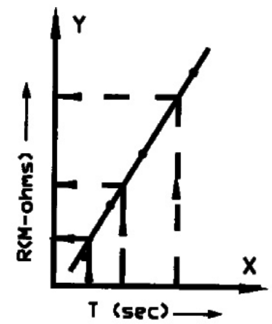
Q.3 *What do you mean by a scalar?*

Ans. It is a device which records directly the counts of the G-M tube pulses.

Date…………

Expt: Neon flash lamp.





Observations and Calculations:

Time period with known resistance:

No. of obs.	Known resistance	Time for 20 flashes			Flashing period
	R	t_1	t_2	$t = \frac{t_1 + t_2}{2}$	$T = t / 20$
	MΩ	sec	sec	sec	sec
1	1	7.4	7.3	7.35	0.37
2					
3					
4					

Time period with unknown resistance:

No. of obs.	Unknown resistance	Time for 20 flashes			Flashing period
	X (from the graph)	t'_1	t'_2	$t'_1 = \frac{t'_1 + t'_2}{2}$	$T' = t' / 20$
	MΩ	sec	sec	sec	sec
1	(1.8)	9.3	9.43	9.4	0.47
2					
3					

From the graph, values of unknown resistances:

R_1 = ____ MΩ, R_2 = ____ MΩ, R_3 = _____ M Ω

The great end of life is not Knowledge but Action. –Thomas Henry Huxley

Home Project:

Find the resistance of the car stereo system which draws 400 mA current, playing with a 12.0V battery: [$R = \Delta V / I$] . Try to find the current I if possible.

Experiment No. 22:

Determination of high resistance by Neon flash lamp.

Apparatus:

Neon lamp, DC power supply (250V), capacitor (0.2μF), known resistances (1,2,3,4,5 MΩ), unknown high resistances, and stop watch.

Theoretical Base:

When a capacitor is charged through a resistor by a DC voltage, the charge increases with time according to the equation,

$$V = V_o (1 - e^{t/RC}) \quad \text{or} \quad V_o - V = V_o e^{t/RC}$$

$$\text{or} \quad \frac{V_o}{V_o - V} = e^{t/RC} \quad \text{or} \quad t = RC \log_e \frac{V_o}{V_o - V}$$

If t_1 be the time for the capacitor to charge up to V_1 volts, and t_2 time for V_2 volts, then the above equation gives,

$$t_1 = RC \log_e \frac{V_o}{V_o - V_1} \quad \text{and} \quad t_2 = RC \log_e \frac{V_o}{V_o - V_2}$$

The **flashing period T** is given by,

$$T = t_1 - t_2 = RC \left(\log_e \frac{V_o}{V_o - V_1} - \log_e \frac{V_o}{V_o - V_2} \right)$$

$$\text{or } T = RC \left(\log_e \frac{V_o - V_2}{V_o - V_1} \right) \quad [\log a - \log b = \log a / b]$$

Procedure:

1) *Make connections according to the circuit diagram.*
2) *Switch on the power supply and record the average time of 20 flashes.*
3) *Complete the first table with known resistances by finding flashing period.*
4) *Insert given unknown resistance X and find time period for the flashes as before.*
5) *Plot a graph between T & R as shown in the fig.*
6) *From the graph read the value of resistance against the flashing period T. This value of resistance is equal to the unknown resistance X.*
7) *Complete the second table by filling unknown resistances from the graph.*

Precautions:

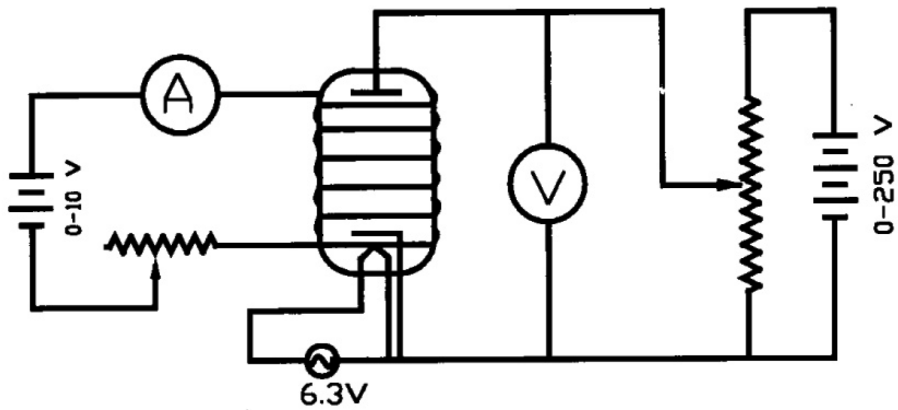
1. Voltage supplied from the D.C. source should exceed the striking voltage.
2. The power supply should supply constant voltage.
3. Resistances should be of order of mega ohms to get measurable time period.

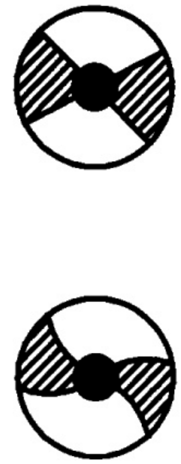
Viva Voce:

Q.1 *What is meant by striking voltage?*
Ans. The potential difference across a neon lamp at which it begins to glow.
Q.2 *What is meant by extinction voltage?*
Ans. That certain voltage at which neon lamp extinguishes.
Q.3 *What do you mean by flashing period?*
Ans. Time between two consecutive glows of the neon lamp.

Date…………

Expt: e/m of electrons.





Observations and Calculations:

Radius of the disc used = R = ____ cm = _____ m
Number of turns per unit length of solenoid = n = ________
Permeability of air = μ = 1.257 x 10^{-6} Weber/m^2

No. of obs.	Anode voltage V (volt)	Solenoid current i (amp)	$B = 4\pi\mu n i$	$e/m = \frac{2V}{B^2 R^2}$
1	130	1.7	2.7 x 10^{-3}	3.57 x 10^{11}
2				
3				
4				

Mean value of e / m = _____ x 10^{11} C / kg

Standard value of e/m = 3.57 x 10^{11} C/kg

Difference = ______ C / kg

Old boys have their playthings as well as young ones; the difference is only in price. *–Benjamin Franklin*

Home Project:
Finding the speed of an electron that moves undeflected, perpendicular to crossed magnetic and electric fields. [v = V / B]. Check whether this speed is same or different when moving in curved path.

Experiment No. 23:

To determine the e/m of electrons by deflection method (teltron tube).

Apparatus:

Magic eye (6AF6 tube), power supplies (0-250V DC & 6.3V AC) and 0-250V DC, Solenoid coil, ammeter, rheostat, circular disc or coin.

Theoretical Base:

An electron moving along a circular path in a uniform magnetic field will experience two forces, *centripetal force* & the *magnetic force*, both balancing each other,

$$Bev = m v^2 / r \quad \text{or} \quad e / m = v / B r \quad \text{…..} (1)$$

If V is the potential difference, then the energy gained by electrons during their acceleration is Ve. This appears as the kinetic energy of electrons,

$$\tfrac{1}{2} m v^2 = Ve \Rightarrow v = \sqrt{2 Ve / m}$$

Substituting the value of v in eq. (1), we have

$$e / m = 2V / B^2 r^2 \quad \text{…..} \quad (2)$$

Teltron tube is a thermionic tube designed to show deflection of moving electrons in an electric field.
Also when current i pass through a solenoide, the magnetic field inside is,

$$B = 4\pi\mu n i$$

Procedure:

1) *Make connections as shown in fig. (a).*
2) *Open the key K and apply anode potential of about 150 volts.*
3) *Look down from top of the tube. You will get a view similar to that of fig. (b).*
4) *Close the key K and allow a suitable current to flow through the solenoid.*
5) *Look again into the tube. You will get view similar to that of fig. (c).*
6) *Note that by changing the solenoid current or plate voltage, the curvature of the shadow changes.*
7) *Place a coin on the top of the solenoid and adjust the current or voltage so that the shadow is nearly equal to the curvature of the disc.*
8) *Note the solenoid current and the plate voltage.*
9) *Complete all the columns of the table and find the mean value of e/m.*

Precautions:

1. Solenoid should be placed in vertical position to eliminate the earth's field.
2. The tube should be placed at the center of the solenoid.
3. Curvature of the edge of the shadow should match with curvature of the disc.

Viva Voce:

Q.1 *At what portion of solenoid the magnetic field is uniform?*
Ans. At the center of the solenoid, the magnetic field will be uniform.
Q.2 *Is it possible to use earth's magnetic field to deflect the electron's beam?*
Ans. No, because the earth's magnetic field is too weak to produce deflection.
Q.3 *How many forces acting on the electron while moving in circular path?*
Ans. Two forces are acting on it; centripetal force & magnetic force.

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Exercises

> 23 for the standard experiments

Nature and Nature's laws lay hid in night;
God said: 'Let Newton be' and all was light.
–Epitaph at Newton's birthplace

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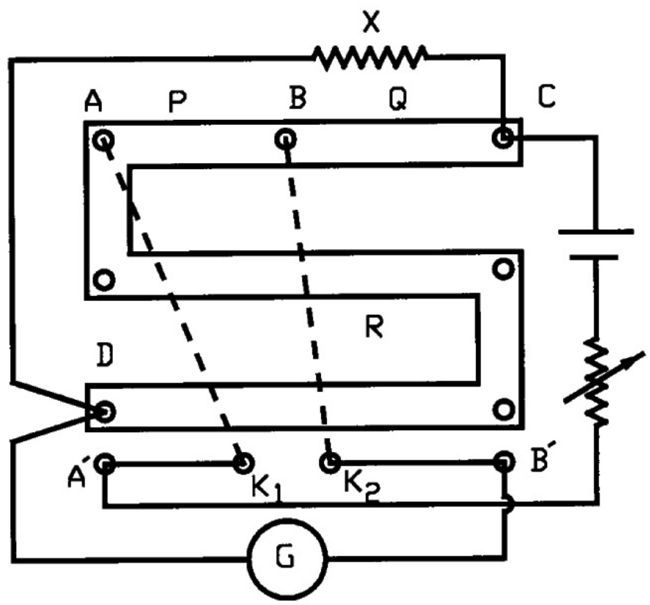
Exercise 1:

To find the resistance of a wire by post office box.



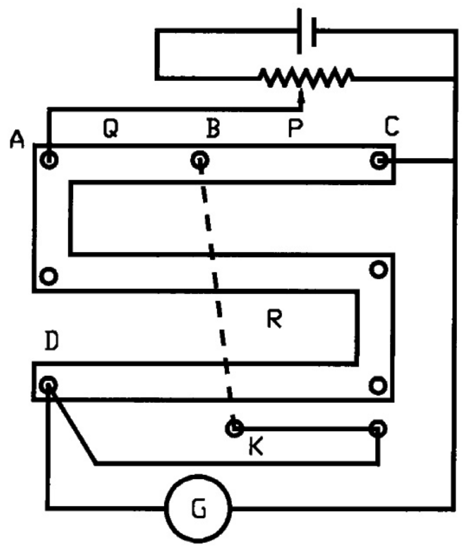
No. of obs.	Ratio arms		Resistance R	Direction of deflection	$X = R\frac{Q}{P}$
	P	Q			
	ohms	ohms	ohms		ohms
1	10	10			
2	10	10			
3	10	10			
4	10	10			
5	100	10			
6	100	10			
7	1000	10			
8	1000	10			

Hints:

Make connections according to circuit diagram.
Take out 10 ohms each from both P and Q arms. First press key K_1 and then key K_2 . Complete the table. Please note that opposite deflection in each case should be of the difference of one ohm. Take mean of last two readings, which give the resistance X of the given wire.

Exercise 2:

To find the resistance of a Galvanometer by Kelvin method.



No. of obs.	P	Q	Resistance R	$G = R \frac{P}{Q}$
	ohms	ohms	ohms	ohms
1	10	10		
2	10	10		
3	10	100		
4	10	100		

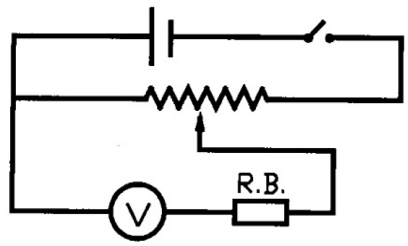
Hints:

Make connections according to circuit diagram. Use a potential divider arrangement for getting a *suitable deflection* in galvanometer. Take out 10 ohms each from P and Q. Adjust R so that on closing and opening the key K there is no change in the deflection. Repeat by taking out 10 and 100 from P and Q for no change, i.e., by taking out two resistances (say 1013 & 1014 ohms) the deflection will be left and right of the *original deflection*. This mean G is between 101.3 & 101.4 ohms. (The 10, 1000 ratio is not sensitive and so is not used.).

Please note that in this method there is always deflection in the galvanometer and it will never zero.

Exercise 3:

To find resistance of a voltmeter without graph.



No. of obs.	Voltmeter reading with R = 0 θ	Voltmeter reading for θ/2	Resistance taken from R.B. for half deflection R_V
	div.	div.	ohms

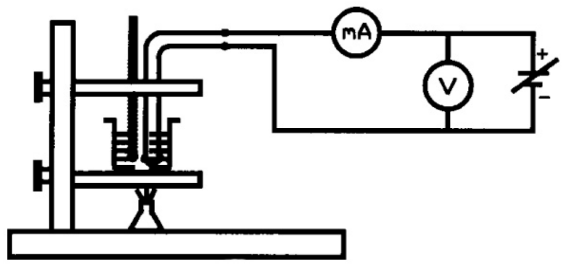
Hints:

Make connections according to circuit diagram.

Get galvanometer deflection θ with R = 0. Then take half deflection θ /2 by taking resistances from the resistance box R. This resistance taken will be the resistance of voltmeter R_V .

Exercise 4:

Variation of resistance of thermister with temperature using voltmeter-ammeter method.



No. of obs.	Temperature	Absolute temperature	Voltage	Current	Resistance R = V / I
	^{o}C	K	volts	μA	ohms
1					
2					
3					
4					
5					
6					
7					

Hints:

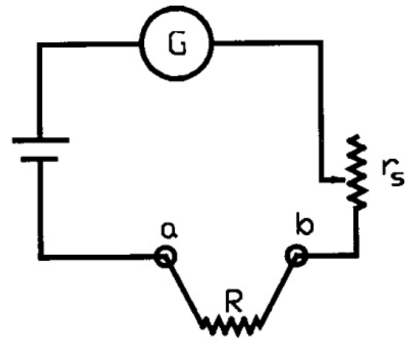
Make connections according to the circuit diagram.

Start heating the beaker till about 90 ^{o}C and fill up all the columns of the table.

Plot a graph between resistance of thermister and absolute temperature. Find the slope of the curve.

Exercise 5:

Convert a galvanometer into ohmmeter.

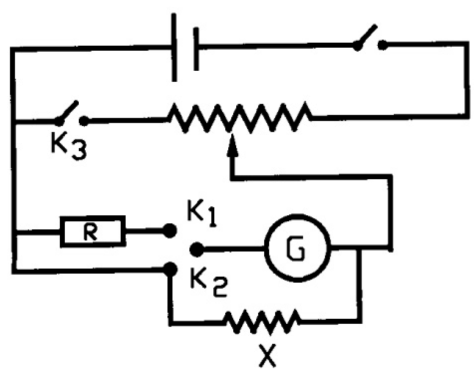


Hints:

Make connections according to the circuit diagram.
Adjust series resistance r_s so that for c and d are short circuited, i.e., R = 0, galvanometer gives full scale deflection. And when c and d are not joined, i.e., $R = \infty$, the deflection is zero. Now a known resistance R is connected across the terminals c and d. The galvanometer deflects to some intermediate point. This point is calibrated, as r. in the same way the whole scale is calibrated into resistance.

Exercise 6:

Combining voltmeter with ammeter in galvanometer conversion.

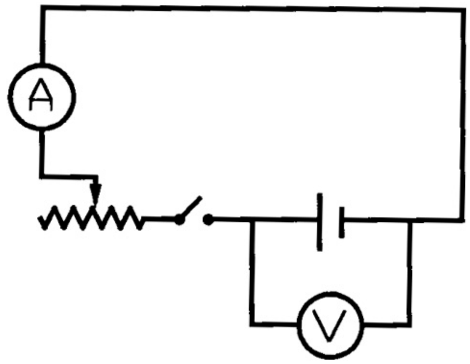


Hints:

Make connections according to the circuit diagram. Here X = *l* and R = R_x of experiments 5 & 6. Now you will combine the two circuits of converted voltmeter and ammeter from galvanometer through a 2-way key, as shown in the figure. For voltmeter readings, close K_1 & K_3. For ammeter readings, close K_2 & open K_3. Adjust the resistances so that you will get proper range of voltmeter readings and ammeter readings on the galvanometer scale.

Exercise 7:

To find the internal resistance of a cell using voltmeter and ammeter.



No. of obs.	Voltmeter reading with key open E	Voltmeter reading with key closed V	Ammeter reading I	Internal resistance $r = \frac{E - V}{I}$
	volts	volts	amp.	ohms
1				
2				
3				

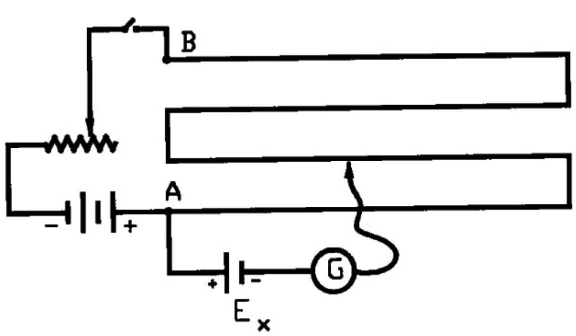
Hints:

Make connections according to the circuit diagram.

With the key open, gives emf E of the battery. With the key closed, voltmeter gives voltage V and current I through the circuit. The formula in the last column of the table will give the internal resistance of the cell.

Exercise 8:

To determine the emf of a cell with Potentiometer using single cell.



Hints:

Make connections according to circuit diagram.

Measure emf E of the battery, length L of the potentiometer, and the distance *l* of the balance point C from end A with the cell E_x . The emf will be

$$E_x = E \times l / L .$$

Exercise 9:

Find temperature coefficient of the resistance of tungsten filament lamp.

Hints:

Put the tungsten bulb in crushed ice for 10 minutes. Measure resistance, R_o between the ends of the filament at 0 ^oC. Now heat up the bulb by making it on with a battery for 10 minutes. Measure its temperature t, and resistance R_t .

apply the formula $\alpha = \dfrac{R_t - R_o}{R_o\, t}$

Exercise 10:

Find the dip angle (i.e., angle between the field angle and horizontal plane) of earth's magnetic field.

Hints:

Reference from Experiment 10:

Calculating magnetic field at the center of the coil ;

$$B = (\mu_o n I / D) = \ldots\ldots..$$

and $H = \dfrac{\mu_o n I r^2}{\tan\theta\, 2 (r^2 + x^2)^{3/2}}$ = ……. [please note factor 2 in denominator]

Now $B = H \tan\theta$ or $\theta = \tan^{-1} B / H$

Check by suspending a small magnet like a compass that is free to swing in a vertical plane.

Exercise 11(a):

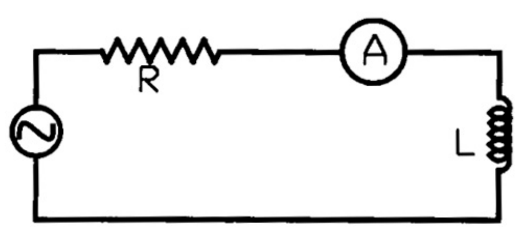
Find energy stored in a charged capacitor.

Hints:

Reference to experiment 11; Take the values of C, R and changing values of current I. Substitute in the equation $E = [½ CV^2 =]\ ½ C I^2 R^2$. Calculate E_{max} , E_{min} and few in between values. Please note that corresponding to I_{max} , energy is E_{max} .

Exercise 11(b):

Find reactance of an inductor, when A.C. current is passing through it.



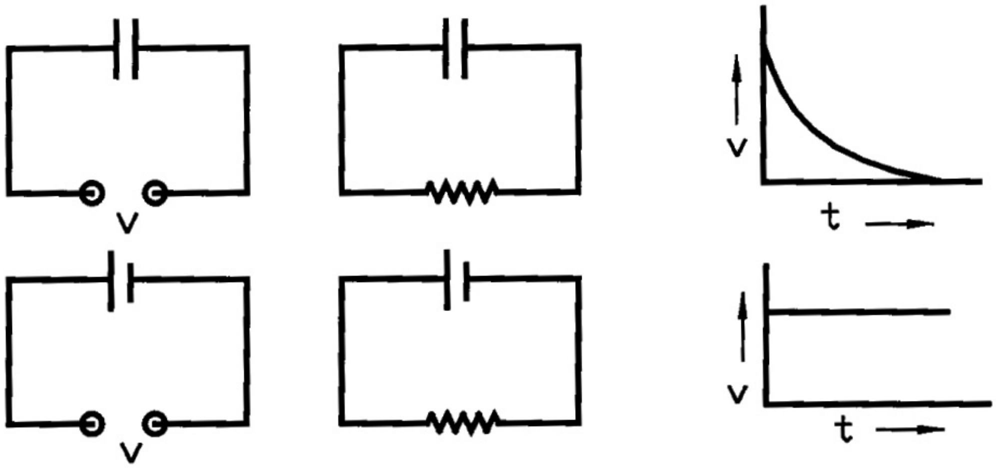
Hints:

Calculate value of: $X_L = V_{rms} / I_{rms}$ = …..

Theoretical value: $X_L = 2\pi f L$ = …..

Exercise 12:

Compare discharging of a capacitor with a battery.



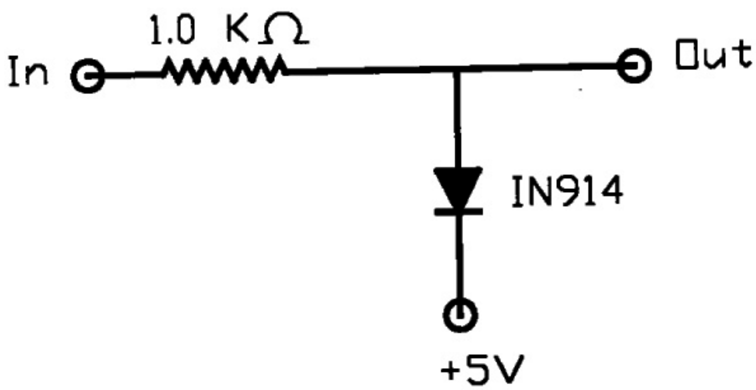
Hints:

Make connections for a capacitor and then for the battery as shown in the circuit diagram. Note different readings for time t verses voltage V in both cases. Plot the both graphs.

Please note that shortening of a battery, by connecting low-resistance wire, even for short periods of time, may damage the battery by draining excessive current.

Exercise 13:

Design a **diode clamp**, i.e., one that prevents it from exceeding + 5.6 volts.

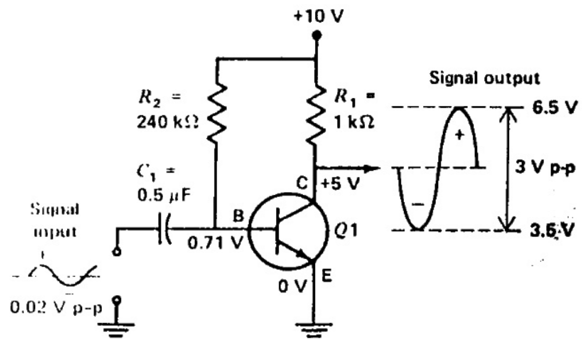


Hints:

Set up the discrete components as shown in the figure. The diode prevents the output from exceeding about +5.6 volts, with no effect on voltages less than that. [Diode clamps are standard equipment on all inputs in the CMOS family of digital logic. Without them, the delicate input circuits are easily destroyed by static electricity discharges during handling.]

Exercise 14:

Set up transistor as an amplifier.



Hints:

Set up the discrete components as shown in the circuit diagram. This is common-emitter amplifier circuit. The NPN transistor is biased so that the collector-to-emitter voltage V_C is half of the supply voltage. The 0.7 V at the base is partially turning on the transistor. The transistor acts as an amplifier when in this partially turned on condition.

Exercise 15:

Tracing the electric current due to intensity of Sunlight using a photocell. And estimate number of photons reaching the surface of Earth per m^2 /sec.

Hints:

Take out in the Sunlight, the box containing photocell and open its lid. Throw sunlight through a mirror upon the photocell. Note the current with a sensitive micro-ammeter.

Calculate energy of a photon. Take average wavelength of sunlight = 500 nm.

$E = hf = h\,(c/\lambda) =$ …….. [$h = 6.63 \times 10^{-34}$ J.s; $c = 3.0 \times 10^{8}$ m/s]

Then calculate n, the number photons per m^2 /sec.

$$n = \frac{\text{Energy per m}^2\text{/sec.}}{\text{Energy per photon}} = \ldots\ldots\ldots$$ [Energy per m^2 /sec. = 1.0×10^3 W/m^2]

Exercise 16:

Find the work function of the surface of the photocell from the data in experiment 16.

Hints:

Plot graph between stopping potential verses frequency [$f = c/\lambda$] , by taking data from the table in experiment 16. The intercept of the straight line on frequency axis is the cutoff frequency f_o . Putting $V_o = 0$ and $f = f_o$ in the equation $V_o e = h f - \phi$, we get

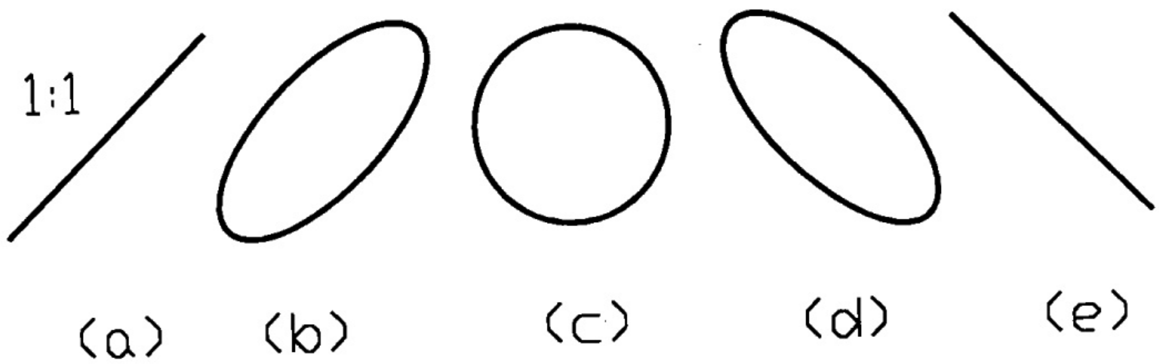
$\phi = hf_o =$ …. J = …. eV

From the slope of the graph, find the value of Planck's constant.

$h = e\,(\Delta V / \Delta f) =$ …. Js

Exercise 17:

Compare the frequency for a variable frequency oscillator by Cathode Ray Oscilloscope.

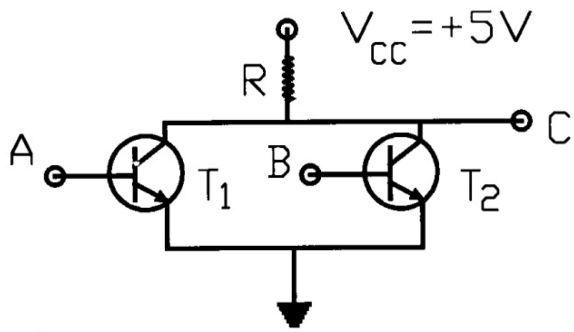


Hints:

In cathode ray oscilloscope, if A.C. voltages are applied simultaneously to the horizontal and vertical deflecting plates, the spot on the screen will produce Lissajous figure shown above. Owing to the phase difference of $\pi / 2$ introduced by a capacitor, the resulting figure on the screen is an ellipse.
If the frequencies are reducible to a common measure, the particle retraces a closed path over and over. If frequencies are very nearly equal, the path changes slowly from straight line at 45^{o} , as in fig. (a), to an ellipse as in fig. (b), and changes so on.

Exercise 18(a):

To verify truth table for NOR gate.

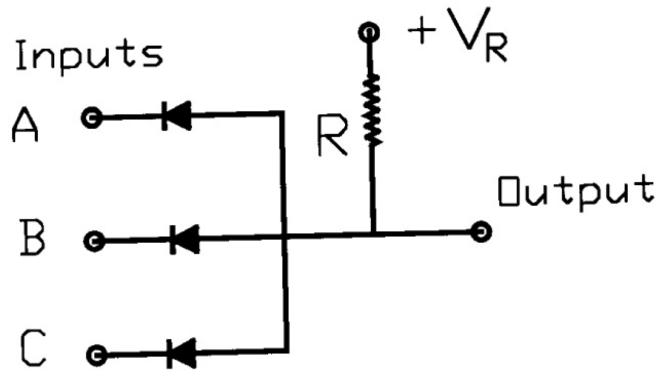


Hints:

Transistor NOR gate is shown in the figure. It is a combination of OR gate followed by NOT gate. When both the inputs A and B are low (0), the two transistors are cut-off and output C is high (1). For any other input combination, both transistors saturate and output C goes to the ground state, i.e., a low (0) output. Write the Truth table for it.

Exercise 18(b):

Make from the diodes a 3-input AND gate.

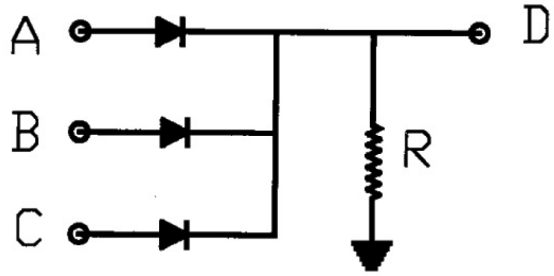


Hints:

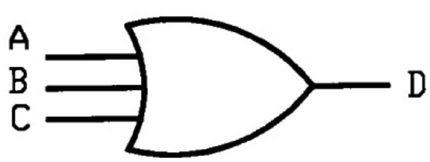
Three input AND gate using diode logic is shown in the figure. The logical level of signal source is $V_{(0)}$ and $V_{(1)}$ for 0 and 1 respectively. V_R is greater than the input level $V_{(1)}$. Write the Truth table for it.

Exercise 18(c):

Verify truth table for 3-input diode OR gate.



Inputs			Output
A	B	C	D
0	0	0	0
1	0	0	0
0	1	0	1
1	1	0	1
0	0	1	1
1	0	1	1
0	1	1	1
1	1	1	1



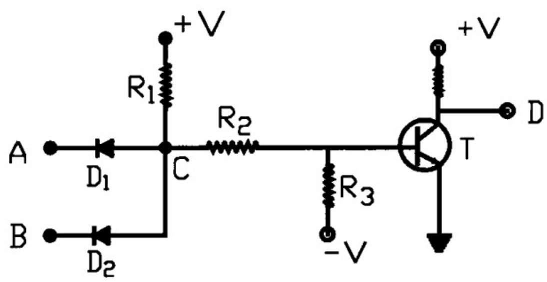
True = +V = 1
False = 0V = 0

Hints:

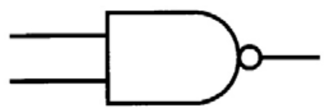
Three input OR gate using diode logic is shown in the figure. The circuit output at D is at +V volts if any input A or B or C is at +V volts. The Truth table lists all the possible input conditions. There is only one condition, the top line, for which the output is false.

Exercise 19:

Verify truth table for NAND gate.



A	B	C	D
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0



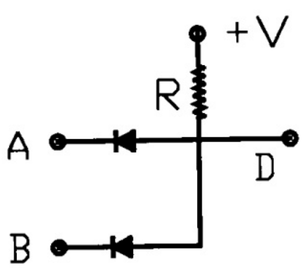
Hints:

The NAND gate circuit is shown in the figure. It is made by connecting the output of AND gate with the input of NOT gate.
The truth table for NAND gate and its symbol is also shown.

Exercise 20:

Verify with the same diode gate circuit AND and OR functions.

(a)



(b)

A	B	D
0	0	0
1	0	0
0	1	0
1	1	1

Voltage

(c)

A	B	D
F	F	F
T	F	F
F	T	F
T	T	T

1 = True
0 = False
AND Gate

(d)

A	B	D
T	T	T
F	T	T
T	F	T
F	F	F

1 = False
0 = True
OR Gate

Hints:

The diode AND circuit is shown in the figure. The truth table usually presents its information by giving values of voltage, expressed as 0 or 1. If 1 voltage is defined as true, then truth table uses T or F. These statements used in fig. (c), are called *positive logic*.
This AND circuit can be used as an OR circuit, by inverting the logic. We must invert the previous statements so that 0 volts is defined as true, while 1 voltage is false. These statements used in fig. (d), are called *negative logic*.

Exercise 21:

Reducing Background effect in the G.M. tube.

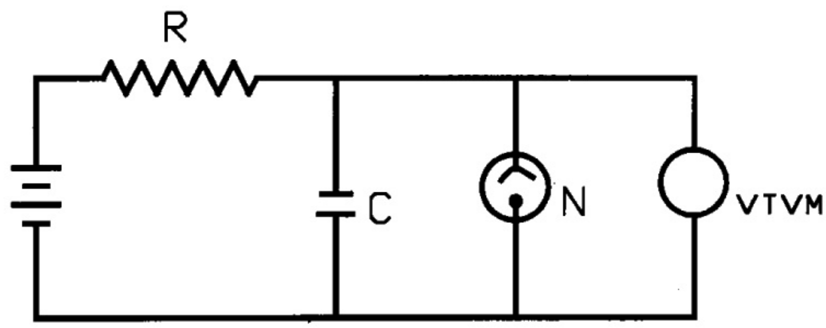
Hints:

Cosmic rays and radioactive contamination are always present as natural background. Screening the counter with a few centimeter of lead can reduce it. Try to find some resources to get lead. Shield the G.M. tube with the lead and note the counting with the scalar.

Try other ways of shielding the tube. Find the difference by bringing sensitive region direct to sunlight. If possible enclosing with some water tank shielding.

Exercise 22:

Determination of high resistance by Neon flash lamp by using different capacitors.



Hints:

Make connections according to circuit diagram.

Note value of striking voltage V for the flash lamp.(Its range is between 150-170 volts). Measure DC main voltage V_o . ($V_o > V$ will be applied).

Simultaneously switch on DC supply and stop watch, read off V and t when the lamp glows. Take a number of readings by using different capacitors and find unknown resistance from the following formula:

$$R = \frac{t}{2.303\, C \log (1 - V / V_o)}$$

Exercise 23:

Find velocity of the moving electrons in the teltron tube.

Hints:

Reference experiment 23; Take average anode voltage V from the table. Apply the formula,

$$v = \sqrt{\frac{2\,Ve}{m}} \qquad [e = 1.61 \times 10^{-19}\ C,\ m = 9.11 \times 10^{-31}\ kg]$$

Tables of Constants & Useful Data

$\pi = 3.14$; $\sqrt{\pi} = 1.773$; $\pi^2 = 9.87$
Sphere's surface area = $4\pi R^2$
Circumference of a circle = $2\pi R$

Area of cross-section = πR^2
Volume of a sphere = $4/3\ \pi R^3$
Volume of a cylinder = $\pi R^2 \times l$

Value of *g* at different places	
Peshawar	970.3 cm/sec^2
Rawalpindi	973.2 cm/sec^2
Lahore	979.0 cm/sec^2
Multan	979.4 cm/sec^2
North pole	983.2 cm/sec^2

Substance	Critical Angle	μ
Crown glass	41°	1.52
Flint glass	37°	1.67
Water	48.5°	1.33
Glycerin	44.5°	1.47
Diamond	24°	2.42
Air	nil	1.00

Elastic constants for wire		
Material	Breaking stress	Young's modulus
	kgm/mm^2	dynes/cm^2
Aluminum	20 to 25	7.2 to 7.5 x 10^{11}
Brass	30 to 90	8 to 10.5 x 10^{11}
Copper	40 to 45	10 to 13 x 10^{11}
Iron	40 to 55	19 to 20 x 10^{11}

Surface Tension	
Substance	Surface tension
Water	72.3 dynes/cm
Kerosene oil	26.3 dynes/cm
Turpentine oil	27.3 dynes/cm
Paraffin oil	26.4 dynes/cm
Alcohol	22 dynes/cm
Mercury	465 dynes/cm

Specific Heat for Solids and Liquids					
Solid	Kcal / kg ^oC	J / Kg ^oC	Liquid	Kcal / kg ^oC	J / Kg ^oC
Aluminum	0.212	903.0	water	1.000	4200.0
Brass	0.088	369.6	Glycerin	0.58	2226.0
Copper	0.094	387.7	Kerosene oil	0.53	2226.0
Glass	0.19	798.0	Castor oil	0.508	2133.6
Iron	0.119	499.8	Olive oil	0.47	1974.0

Coefficients of Linear Expansion ($^oC^{-1}$)			
Aluminum	0.000023	Silver	0.000019
Brass	0.000019	Iron	0.000011
Copper	0.000017	Platinum	0.000009
Glass	0.000008	Ice	0.000051

Coefficients of Viscosity					
Water	.01793 at 0 ^0C	.01142at 15 ^0C	.01006at 20 ^0C	.00902at 50 ^0C	.00012at100 ^0C
Air	.00017at 0 ^0C	.00018at 15 ^0C	Mercury	.016 at 20 ^0C	.00532at100 ^0C
Ether	.00234at 20 ^0C	.000097at100 ^0C	Alcohol	.0119at 20 ^0C	.00011at100 ^0C

Wavelength of light: Sodium (yellow) = 5896 A.U. = 5.9 x 10^{-7} m
Laser (red) = 6800 A.U. = 6.8 x 10^{-7} m

Velocity of Sound in: Air at 0 ^oC = 331.3 m/sec; Increase for 1 ^oC = 61 cm/sec
Water at 15 ^oC = 1450 m/sec, Copper at 20 ^oC = 3560 m/sec, Steel = 5000 m/sec

Conversion Factors

1 inch = 2.54 cm = 0.0255 meter, 1 meter = 100 cm = 39.37 inch
1 Newton = 10^5 dynes, 1 calorie = 4.18 joules, 1 Joule = 10^7 erg = 0.239 calorie
1 litre = 1000 c.c., 180 = π radians, 1 radian = 57.3^o , 1 mile = 1.61 km

Some Fundamental Constants

Velocity of light	c	2.9979×10^{8} m/s = 186,000 miles/s
Elementary charge	e	1.6021×10^{-19} C
Electron rest mass	m_e	9.1091×10^{-31} kg
Proton rest mass	m_p	1.6725×10^{-27} kg = 1.008 amu= 1836 electron masses
Neutron rest mass	m_n	1.6748×10^{-27} kg = 1837 electron masses
Planck's constant	h	6.6256×10^{-34} J.s.
e/m for electron	e/m_e	1.7588×10^{11} kg^{-1} C
Rydberg constant	R	1.0974×10^{7} m^{-1}
Avogadro constant	N_o	6.0225×10^{23} mol^{1}
Boltzmann constant	$k = R/N_o$	1.3805×10^{-23} J $K^{o\,-1}$
Universal gas constant	R	8.3143 J $K^{o\,-1}$ mol^{-1}
Vacuum permittivity	ε_o	8.8544×10^{-12} N^{-1} m^{-2} C^{2}
Vacuum permeability	μ_o	1.3566×10^{-6} m kg C^{-2}
Acceleration of gravity	g	9.7805 m s^{-2}
Gravitational constant	G	6.673×10^{-11} N-m^{2} /kg^{2}
One atomic mass unit	μ (C^{12})	1.66×10^{-27} kg = 931 Mev = 1.49×10^{-10} J
1 electron volt	E eV	1.501×10^{-12} erg
Stefan-Boltzmann constant	K	5.6697×10^{-8} W m^{-2} $K^{o\,-4}$
Bohr magneton	$\mu_B = eh/2m_e$	9.274×10^{-24} J T^{-1}

Electromotive force & composition of voltaic cells

Electromotive force is that which causes a flow of current. The electromotive force of a cell is measured by the maximum difference of potential between its plates.

Standard Cells

Name of cell	Negative pole	Solution	Positive pole	Depolarizer	EMF in volts
Weston normal	Cadmium amalgam	Saturated solution of $CdSO_4$	Mercury	Paste of $Hg_2 SO_4$ & $CdSO_4$	1.0183 at 20^{o} C
Clark standard	Zinc amalgam	Saturated solution of $ZnSO_4$	Mercury	Paste of $Hg_2 SO_4$ & $ZnSO_4$	1.4328 at 15^{o} C

Double Fluid Cells

Name of cell	Negative pole	Solution	Positive pole	Solution	EMFin volts
Bunsen	Amal. Zinc	1 part $H_2 SO_4$ to 12 parts $H_2 O$	Carbon	HNO_3 , density1.38	1.86
Daniell	Amal. Zinc	1 part $H_2 SO_4$ to 4 parts $H_2 O$	Copper	Saturated solution of $CuSO_4 + 5H_2 O$	1.06

Single Fluid Cells

Name of cell	Negative pole	Solution	Positive pole	E.M.F. in volts
Dry cell	Zinc	Ammonium Chloride	Carbon with MnO_2	1.53
Leclanche	Amal. Zinc	Solution of sal-ammoniac	Manganese peroxide with powd. carbon	1.46

Resistance

Definition: It is a property of conductors depending on their dimensions, material and temperature when determines the current produced by a given difference of potential. The practical unit is ohm.

Resistance of a conductor at 0 °C, of length *l*, cross-section *s* and specific resistance ρ,

$$R_o = \rho \frac{l}{s}$$

Resistance of wires

B. & S. Gauge	Diameter in mm.	Ohms per cm	B. & S. Gauge	Diameter in mm.	Ohms per cm
Constantan (0 °C) $\rho = 44.1 \times 10^{-6}$ ohm-cm			Nichrome $\rho = 100 \times 10^{-6}$ ohm-cm		
10	2.588	.000838	10	2.588	.00190
12	2.053	.00133	12	2.053	.00302
14	1.628	.00212	14	1.628	.00481
16	1.291	.00337	16	1.291	.00764
20	0.8118	.00852	20	0.8118	.0193
24	0.5106	.0215	24	0.5106	.0489
28	0.3211	.0545	28	0.3211	.123
32	0.2019	.138	32	0.2019	.312
36	0.1270	.348	36	0.1270	.789
40	0.07987	.880	40	0.07987	2.00
Copper $\rho = 1.724 \times 10^{-6}$ ohm-cm			Platinum $\rho = 10 \times 10^{-6}$ ohm-cm		
10	2.588	.0000328	10	2.588	.000190
12	2.053	.0000521	12	2.053	.000302
14	1.628	.0000828	14	1.628	.000481
16	1.291	.000132	16	1.291	.000764
20	0.8118	.000333	20	0.8118	.00193
24	0.5106	.000842	24	0.5106	.00489
28	0.3211	.00213	28	0.3211	.0123
32	0.2019	.00538	32	0.2019	.0312
36	0.1270	.0136	36	0.1270	.0789
40	0.07987	.0344	40	0.07987	.200
Eureka (0 °C) $\rho = 47 \times 10^{-6}$ ohm-cm			Steel (0 °C) $\rho = 11.8 \times 10^{-6}$ ohm-cm		
10	2.588	.000893	10	2.588	.000224
12	2.053	.00142	12	2.053	.000357
14	1.628	.00226	14	1.628	.000567
16	1.291	.00359	16	1.291	.000901
20	0.8118	.00908	20	0.8118	.00228
24	0.5106	.0230	24	0.5106	.00576
28	0.3211	.0580	28	0.3211	.0146
32	0.2019	.147	32	0.2019	.0368
36	0.1270	.371	36	0.1270	.0931
40	0.07987	.938	40	0.07987	.236
Iron $\rho = 10 \times 10^{-6}$ ohm-cm			Tungsten $\rho = 5.51 \times 10^{-6}$ ohm-cm		
10	2.588	.000190	10	2.588	.000105
12	2.053	.000302	12	2.053	.000167
14	1.628	.000481	14	1.628	.000265
16	1.291	.000764	16	1.291	.000421
20	0.8118	.00193	20	0.8118	.00106
24	0.5106	.00489	24	0.5106	.00269
28	0.3211	.0123	28	0.3211	.00680
32	0.2019	.0312	32	0.2019	.0172
36	0.1270	.0789	36	0.1270	.0435
40	0.07987	.200	40	0.07987	.110

Specific resistance or resistivity (ρ):

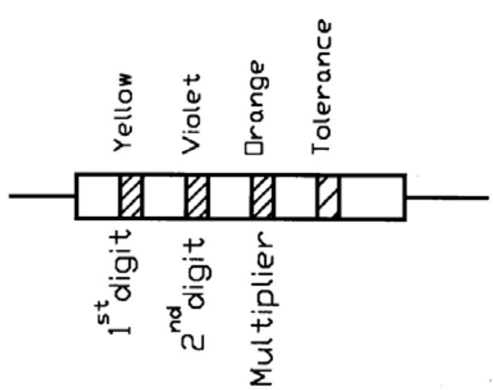
<u>Definition:</u> It is the reciprocal of conductivity, is measured by the resistance of a body of the substance of unit cross-section and of unit length at 0 °C also called **<u>volume resistivity</u>**. The unit may be defined as the ohm-centimeter.
Mass resistivity is the longitudinal resistance per unit length of a uniform bar of the substance of such a sectional areas that it contains one unit of mass per unit length.
Surface resistivity is the resistance of unit length and unit width of a surface.

Material	Temp °C	Resistivity ohm-cm	Material	Temp °C	Resistivity ohm-cm
Aluminum	20	2.828 $x10^{-6}$	Mercury	20	95.783 $x10^{-6}$
Brass	0	6.4—8.4 $x10^{-6}$	Molybdenum	20	5.7 $x10^{-6}$
Carbon	0	3500 $x10^{-6}$	Nichrome	20	100 $x10^{-6}$
Chromium	0	2.6 $x10^{-6}$	Nickel	20	7.8 $x10^{-6}$
Copper	20	1.72 $x10^{-6}$	Platinum	20	10 $x10^{-6}$
Eureka	0	48 $x10^{-6}$	Platinum-iridium	0	24 $x10^{-6}$
German silver, Ni	20	33 $x10^{-6}$	Rose metal [Bi49,Pb28,Sm23]	0	64 $x10^{-6}$
Gold pure	20	2.44 $x10^{-6}$	Silver	0	2.4 $x10^{-6}$
Iron	20	10 $x10^{-6}$	Sodium	-180	1.0 $x10^{-6}$
Steel	20	64 $x10^{-6}$	Tin	-180	3.40 $x10^{-6}$
Manganin	20	44 $x10^{-6}$	Tungsten	20	5.51 $x10^{-6}$

Colour code for resistors

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

Colour bands interpretation:
1. First band indicates the first significant figure.
2. The send band gives second significant figure.
3. The third band gives actual resistance; it is decimal multiplier.
4. The fourth band gives tolerance.



<u>Example</u>: A resistor whose bands are yellow, violet, and orange has a resistance of 47,000 Ω or green, blue, green signifies 5,600,00 , or 5.6 M Ω.
A fourth band of either gold or silver tells the tolerance.

Internal resistance of various voltaic cells

The following values are approximate. It is a subject of large variations.

Cell	Resistance in ohms	Cell	Resistance in ohms
Daniell	0.85	Leclanche	0.4—0.2
Silver Chloride	4	Storage	0.004—0.02
Dry cell	0.05—0.10	Weston standard	20—50

Magnetic fields in the Solar System

Planet	μ (A.m^2)	B at Surface (μT)
Mercury	5×10^{19}	0.35
Venus	$< 10^{19}$	< 0.01
Earth	8.0×10^{22}	30
Mars	$< 2 \times 10^{18}$	< 0.01
Jupiter	1.6×10^{27}	430
Saturn	4.7×10^{25}	20
Uranus	4.0×10^{24}	10-100
Neptune	2.2×10^{24}	10-100

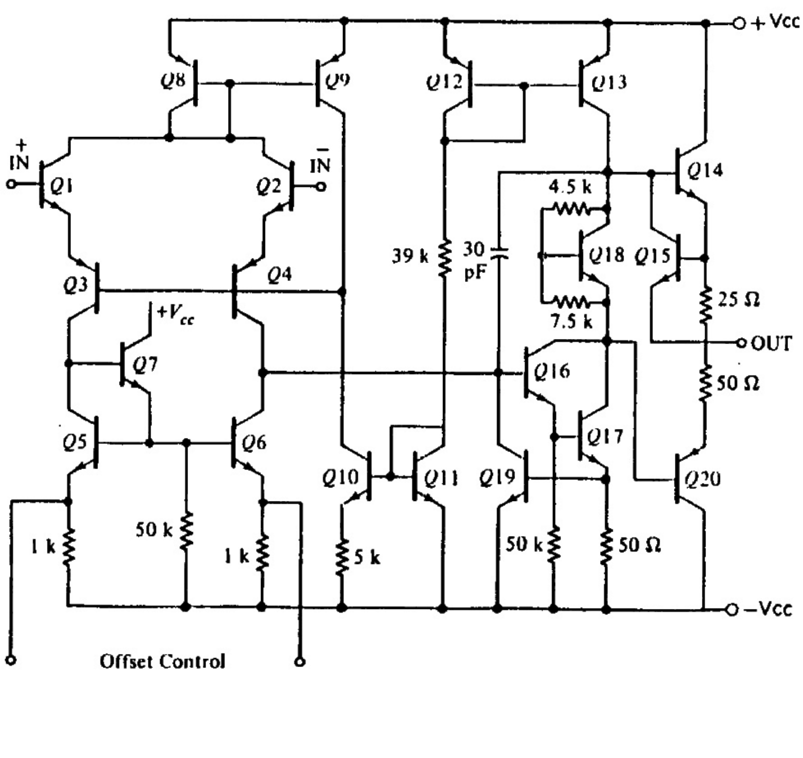
Some Magnetic Elements

Dip: The angle measured in a vertical plane exerted on unit charge. Unit field intensity is the field, which exerts the force of one dyne on unit positive charge.

Values of magnetic elements at some places. (1 gamma = 0.00001 C.G.S. Units)

Place	Declination	Angle of Dip	Horizontal force	Vertical force
Lahore	1^o East	47^o 23.9′	32,950 gammas	35,830 gammas
Karachi	1^o East	36^o 48.3′	35,550 gammas	26,600 gammas
Peshawar	2^o East	51^o 29.1′	31,000 gammas	38,950 gammas
Quetta	1.25^o East	45^o 36.1′	33,000 gammas	33,700 gammas

<u>An OP-AMP</u>: Schematic of the 741 type of internally compensated integrated circuit(IC).



Natural Trigonometric Functions

Angle	Sine	Cosine	Tangent	Angle	Sine	Cosine	Tangent
1°	.018	.999	.018	46°	.719	.695	1.036
2°	.035	.999	.035	47°	.731	.682	1.072
3°	.052	.999	.052	48°	.743	.669	1.111
4°	.070	.998	.070	49°	.755	.656	1.150
5°	.087	.996	.087	50°	.766	.643	1.192
6°	.105	.995	.105	51°	.777	.629	1.235
7°	.122	.993	.123	52°	.788	.616	1.280
8°	.139	.990	.141	53°	.799	.602	1.327
9°	.156	.988	.158	54°	.809	.588	1.376
10°	.174	.985	.176	55°	.819	.574	1.428
11°	.191	.982	.194	56°	.829	.559	1.483
12°	.208	.978	.213	57°	.839	.545	1.540
13°	.225	.974	.231	58°	.848	.530	1.600
14°	.242	.970	.249	59°	.857	.515	1.664
15°	.259	.966	.268	60°	.866	.500	1.732
16°	.276	.961	.287	61°	.875	.485	1.804
17°	.292	.956	.306	62°	.883	.469	1.881
18°	.309	.951	.325	63°	.891	.454	1.963
19°	.326	.946	.344	64°	.899	.438	2.030
20°	.342	.940	.364	65°	.906	.423	2.145
21°	.358	.933	.384	66°	.914	.407	2.246
22°	.375	.927	.404	67°	.921	.391	2.356
23°	.391	.921	.425	68°	.927	.375	2.475
24°	.407	.914	.445	69°	.934	.358	2.655
25°	.432	.906	.466	70°	.940	.342	2.748
26°	.438	.899	.488	71°	.946	.326	2.904
27°	.454	.891	.510	72°	.951	.309	3.078
28°	.469	.883	.525	73°	.956	.292	3.271
29°	.485	.875	.554	74°	.961	.276	3.487
30°	.500	.866	.577	75°	.966	.259	3.732
31°	.515	.857	.601	76°	.970	.242	4.011
32°	.530	.848	.625	77°	.974	.225	4.331
33°	.545	.839	.649	78°	.978	.208	4.705
34°	.559	.829	.675	79°	.982	.191	5.145
35°	.574	.819	.700	80°	.986	.174	5.671
36°	.588	.809	.727	81°	.988	.156	6.314
37°	.602	.799	.754	82°	.990	.139	7.115
38°	.616	.788	.781	83°	.993	.122	8.144
39°	.629	.777	.810	84°	.995	.106	9.514
40°	.643	.766	.839	85°	.996	.087	11.43
41°	.656	.755	.869	86°	.998	.070	14.30
42°	.669	.743	.900	87°	.999	.062	19.80
43°	.682	.731	.933	88°	.999	.030	28.64
44°	.695	.719	.966	89°	.999	.018	57.29
45°	.707	.707	1.000	90°	1.000	.000	∞

An example of calculating sines or tangents of intermediate angles: To find sin 57.8 ; sin 57 is .839 and sin 58 is .848. the difference is .009 for 10 and .0009 for 1 of a degree. Therefore sin 57.8 is .839 + .0072 = .846 .

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