PHYSICS II

Laboratory Manual

(Companion to Physics 102 or Physics 152)

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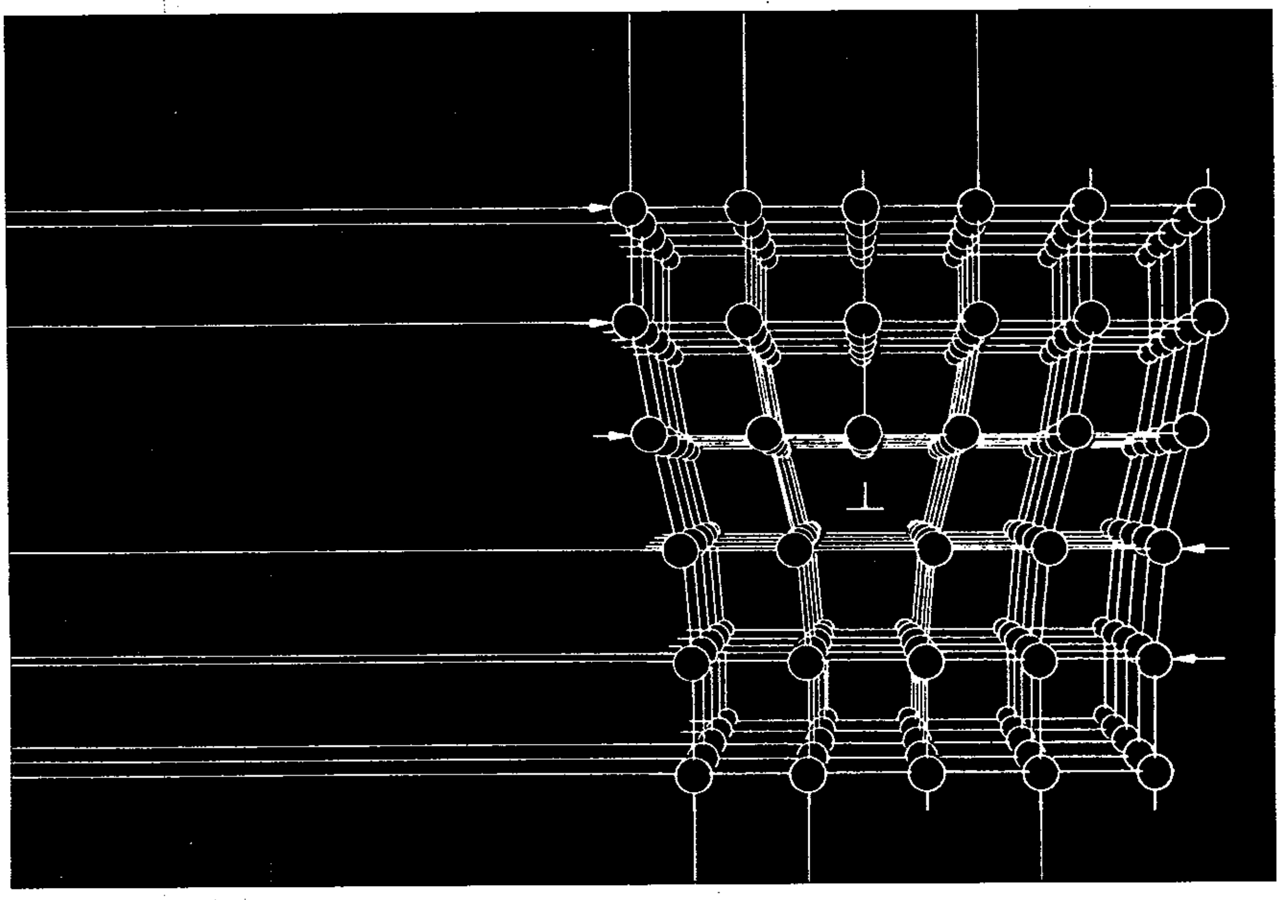

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PREFACE

One purpose of the freshman physics laboratory is to illustrate and clarify the physical concepts which are discussed in the lecture/recitation part of the freshman physics courses. However, there are practical difficulties in keeping the laboratory course in phase with the lecture course. Further, in many instances, the instructor does not have sufficient time to dwell upon the details of the laboratory experiments in lecture/recitation or in the laboratory. Therefore, outlines of the basic theory of the experiments, description of the apparatus and the method of processing laboratory data have been provided in the laboratory manual.

I am grateful to my colleagues for their cooperation and assistance. In particular, I appreciate the support and helpful comments of Prof. F. R. Pomilla and Prof. E. M. Levin.

- D. C. J.

This material is based upon the work supported by the National Science Foundation under Grant No. SER 77-05406.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

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INTRODUCTION

How To Make A Good Grade In A Lab Course Without Really Trying

A laboratory course may seem to involve a lot of work for too few credits. However, remembering the following points may help:

A. A laboratory course supplements the lecture course and helps the students grasp the basic concepts of the subject.

B. A laboratory course teaches the students to be systematic and organized.

C. A laboratory course helps the students realize the distinction between 'exact' theoretical concepts and limitations of 'physical reality' of experimental work.

A Few Simple Rules:

1. Learn the basic theory of the experiment, working of the various pieces of equipment used in the experiment and the procedure of the experiment. Read the experiment, become familiar with the data sheet and answer the pre-lab questionnaire before coming to the laboratory.

2. In the laboratory, follow the steps of the procedure as described in the laboratory manual and record the observations as they appear in the data sheet. The readings should be recorded correct to the least count of the instruments. In general, if estimation is to be done, it should be done correct to half of the value of the smallest division on the scale of the measuring device. Units must be entered where necessary.

3. It is a good practice to make a copy of the data sheet in the note book, perform the calculations and then transfer the data onto the data sheet. Use scientific notation where necessary and avoid non-significant figures.

4. Prepare the laboratory report as soon as possible and submit the report on time.

Physical Quantities and Units:

Scientific work involves dealing with physical quantities - quantities that can be measured. Examples of physical quantities are length, mass, time, velocity, force, momentum, energy, etc. Of these, length, mass and time are the fundamental physical quantities. Other physical quantities can be expressed as suitable combinations of length, mass and time. For example, the velocity of a glider can be obtained by measuring its displacement in a given time interval.

Systems of Units:

System	Length	Mass	Time
MKS system	meter (m)	kilogram (kg)	second (s or sec)
cgs system	centimeter (cm)	gram (g or gm)	second (s)
British system or FPS system	foot (ft)	pound (lb)*	second (s)

* In fact, pound is a unit of force. However, in everyday life, it is used as unit of mass, that is, quantity of matter whose weight is 1 pound. The proper unit of mass in FPS system is a slug, which is the mass in which the force of 1 pound produces an acceleration of 1 ft/s^2. 1 slug is equal to 14.59 kg.

The units must be consistent in all calculations.

The units of some physical quantities are presented in the following table:

Physical quantity	cgs unit	MKS unit	Definition
Volume	cm^3	m^3	volume = length x width x height
Density	gm/cm^3	kg/m^3	density = mass/volume
Velocity	cm/s	m/s	velocity = displacement/time
Acceleration	cm/s^2	m/s^2	acceleration = velocity/time
Momentum	gm.cm/s	kg.m/s	momentum = mass x velocity
Force*	dyne	newton	force = mass x acceleration
Energy	erg	joule	energy = work = force x displacement

* Sometimes, force is measured in gm-wt (gram-weight) which is the force of gravity of the earth on a mass of 1 gram.

In a given laboratory experiment, all data should be obtained and recorded either in MKS or cgs units. In electrical experiments, the following units are used: Volt (V) - unit of potential difference; ampere (A) - unit of current; ohm (Ω) - unit of resistance.

Scientific Notation:

Very large and very small numbers are handled more conveniently in scientific notation. Thus numbers like 2570, 14300 and 0.00056 should be written as 2.57×10^3, 1.43×10^4 and 5.6×10^{-4}, respectively. As a rule, numbers larger than 1000 and smaller than 0.001 should be expressed in scientific notation.

Significant figures:

In a number, all nonzero digits and the zeros that are not used to define the position of the decimal point are significant. This is illustrated in the following table.

Number	Number of significant figures
1.27	3
420	2
420.	3
0.023	2
0.0403	3

Rules for determining the number of significant figures in the result:

(i) Conventionally, at most one more decimal digit can be retained than the certainty of the result.

(ii) In addition and subtraction, the sum or difference has significant figures only in the decimal places where the original numbers have significant figures. Thus

$$\begin{array}{r} 6.843 \\ +\ 0.002 \\ \hline 6.845 \end{array} \qquad \begin{array}{r} 500 \\ -\ 4 \\ \hline 500 \end{array} \qquad \begin{array}{r} 600. \\ +\ 7 \\ \hline 607 \end{array}$$

(iii) In multiplication and division, the result can not have more significant figures than the least accurately known numbers. Thus $2.4 \times 5.8 = 14$; $2.413 \times 5.8 = 14$; $\frac{44}{7} = 6$; $\frac{44}{7.1} = 6.2$.

In intermediate steps of calculation, generally, an extra significant figure is carried.

Error Analysis: Standard Deviation and Standard Error:

Errors are part of physical reality. In most cases, an error-free result may be obtained accidentally due to cancellation of errors or due to negligence. Some errors are accountable such as errors caused due to inaccurate graduation of a scale. Other errors are unaccountable. These are random errors, mistakes in reading the scale and recording of values, etc.

To avoid mistakes, it is a good practice to take at least 2 readings independently, even though only one reading is to entered in the data sheet. If any reading is substantially different from the other readings, it should be discarded or replaced, if necessary.

If only a few (about 3) readings are taken, the probable error can be considered to be equal to the least count of the instrument (the smallest value of a physical quantity that can be measured by the instrument). Thus the length of a cylinder, obtained with a meter stick, will have a probable error of 0.1 cm, if the scale is graduated in mm. Such a reading can be recorded as 12.3 ± 0.1 cm, if the average of the readings of the length of the cylinder is 12.3 cm.

If a number of readings (about 6) are taken, standard deviation and standard error can be used.

Standard Deviation:

Let n readings $x_1, x_2, x_3, \ldots x_n$ be taken. Their arithmetic mean (average) is $\bar{x}$ is defined as

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots x_n}{n}.$$

Standard deviation is defined as

$$\sigma = \sqrt{\frac{(x_1-\bar{x})^2 + (x_2-\bar{x})^2 + (x_3-\bar{x})^2 + \ldots (x_n-\bar{x})^2}{n}}.$$

Finally, the standard error of the mean is defined as

$$\sigma_m = \frac{\sigma}{\sqrt{n-1}}.$$

An Example:

Two students, A and B, measure the length of an object with a meter stick and obtain the following values:

Number	Student A' s data		Student B's data	
	x, length (cm)	$x - \bar{x}$	x, length (cm)	$x - \bar{x}$
1	31.4	-0.07	31.5	0.03
2	31.5	0.03	31.7	0.23
3	31.5	0.03	31.3	-0.17
4	31.4	-0.07	31.9	0.43
5	31.5	0.03	31.1	-0.37
6	31.5	0.03	31.2	-0.27
7	31.5	0.03	31.6	0.13
8	31.4	-0.07	31.5	0.03
9	31.5	0.03	31.3	-0.17
10	31.5	0.03	31.6	0.13

Results	Student A's data	Student B's data
Mean $\bar{x}$	31.47 cm	31.47 cm
σ	0.046 cm	0.232 cm
σ_m	0.015 cm	0.078 cm
Probable percent error*	0.05 %	0.25 %

* Taking probable error equal to σ_m.

Note that although the mean value in both sets of data is 31.47 cm, the standard deviation and standard error in the first set are smaller than those in the second set. Thus the first set of data is better than the second set.

Percent Errors:

$$\text{Probable percent error} = \frac{\text{Probable error}}{\text{Experimental value}} \times 100\ \%.$$

If the standard value of the physical quantity is known, the percent error can be calculated by the formula

$$\text{Percent error} = \frac{(\text{Experimental value} - \text{standard value})}{\text{Standard value}} \times 100\ \%.$$

Propagation of Errors:

The final experimental value of a physical quantity is obtained by a series of steps of calculations. Thus errors in the experimental data lead to errors in the final result. The following rules are applied to determine the probable error in the result:

(i) In addition and subtraction, the probable error in the result is the sum of the absolute values of the probable errors in the individual quantities which are used in the addition or subtraction. For example,

17.9 ± 0.2	(probable % error = 1.1 %)	14.8 ± 0.5	(probable % error = 3.4 %)
$+\ 24.3 \pm 0.1$	(probable % error = 0.4 %)	$-\ 7.9 \pm 0.2$	(probable % error = 2.5 %)
----------		----------	
42.2 ± 0.3	(probable % error = 0.7%)	6.9 ± 0.7	(probable % error = 10 %)

Note that in subtraction, the probable percent error in the result is considerably larger than the probable percent error in the individual quantities.

(ii) In multiplication and division, the probable percent error in the result is equal to the sum of the probable percent errors in the individual quantities. For example, consider the following data:

Length of a cylinder, $\ell = 5.4 \pm 0.1$ cm

(probable percent error = 2%)

Radius of the cylinder, $r = 1.24 \pm 0.05$ cm

(probable percent error = 4%)

Volume of the cylinder,

$V = \pi r^2 \ell = \pi \times 1.24^2 \times 5.4 \text{ cm}^3$

$= 26.07154$ cm (as given by the calculator

Probable percent error in V = probable percent error in ℓ

+ 2x(probable percent error in r)

= 2 + 2x4 % = 10%

Here r appears as r^2 in the formula for V. Thus the probable percent error in r has to be added twice in obtaining the probable percent error in V.

Note that the probable percent error in volume V is 10%. Thus the probable error in V is 2.6 cm^3. Accordingly, the volume should be reported as 26 cm^3 or at most 26.1 cm^3. All other digits given by the calculator are not significant.

Further remember that quantities like r in the above example, which are small and are raised to higher powers in the calculations must be measured more accurately.

Examples of Propagation of Errors:

The following examples illustrate propagation of errors:

Error in the sum of two numbers:

Let x = 17.9 ± 0.2 and y = 24.3 ± 0.1.

Maximum value of x + y = (17.9 + 0.2) + (24.3 + 0.1) = 42.2 + 0.3

Minimum value of x + y = (17.9 - 0.2) + (24.3 - 0.1) = 42.2 - 0.3

Thus the error in the sum = sum of the absolute values of errors
= 0.2 + 0.1 = 0.3.

Error in the difference of two numbers:

Let p = 14.8 ± 0.5 and q = 7.9 ± 0.2.

Maximum value of p - q = (14.8 + 0.5) - (7.9 - 0.2) = 6.9 + 0.7

Minimum value of p - q = (14.8 - 0.5) - (7.9 + 0.2) = 6.9 - 0.7

Thus the error in the difference = sum of the absolute values of errors in p and q
= 0.5 + 0.2 = 0.7

Errors in the results of multiplication and division:

Let x = 5.4 ± 0.2 (% error = 3.7 %) and y = 3.0 ± 0.1 (% error = 3.3 %).

Value of the product xy = 5.4 x 3.0 = 16.2.

Maximum value of xy = (5.4 + 0.2)(3.0 + 0.1) = 17.36 = 16.2 + 1.16.

Percent error in the maximum value of xy = 7.2 %.

Minimum value of xy = (5.4 - 0.2)(3.0 - 0.1) = 15.08 = 16.2 - 1.12.

Percent error in the minimum value of xy = 6.9 %.

Value of $\frac{x}{y} = \frac{5.4}{3.0} = 1.8$.

Maximum value of $\frac{x}{y} = \frac{5.4 + 0.2}{3.0 - 0.1} = 1.93 = 1.8 + 0.13$.

Percent error = 7.2 %

Minimum value of $\frac{x}{y} = \frac{5.4 - 0.2}{3.0 + 0.1} = 1.68 = 1.8 - 0.12$.

Percent error = 6.7 %

Note that in each case, the percent error in the result is nearly equal to the sum of the percent errors in x and y.

GRAPH - An Example

Given the data:

t (sec)	0	5	8	12	17
v (cm/sec)	17	22	26	31	38

We note that t is the independent variable. Thus t should be plotted along the x-axis, and v, along the y-axis.

Suppose the graph paper has 70 divisions along the x-axis and 100 divisions along the y-axis. (Remember that this is just an example.)

First, we choose (x_o, y_o), where x_o is the minimum value of t to be represented and y_o is the minimum value of v to be represented. In the present example, $x_o = 0$ and $y_o = 17$ cm/sec, but for convenience, we will choose $y_o = 10$ cm/sec.

The maximum values of t and v are 17 sec and 38 cm/sec, respectively.

Thus, along the x-axis, (17 - 0) sec are to be represented by 70 divisions.

Or 1 sec can be represented by 70/17 = 4.11 divisions.

For convenience, we will represent 1 sec by 4 divisions.

Along the y-axis, (38 - 10) cm/sec are to be represented by 100 divisions.

Or 1 cm/sec can be represented by 100/28 = 3.57 divisions.

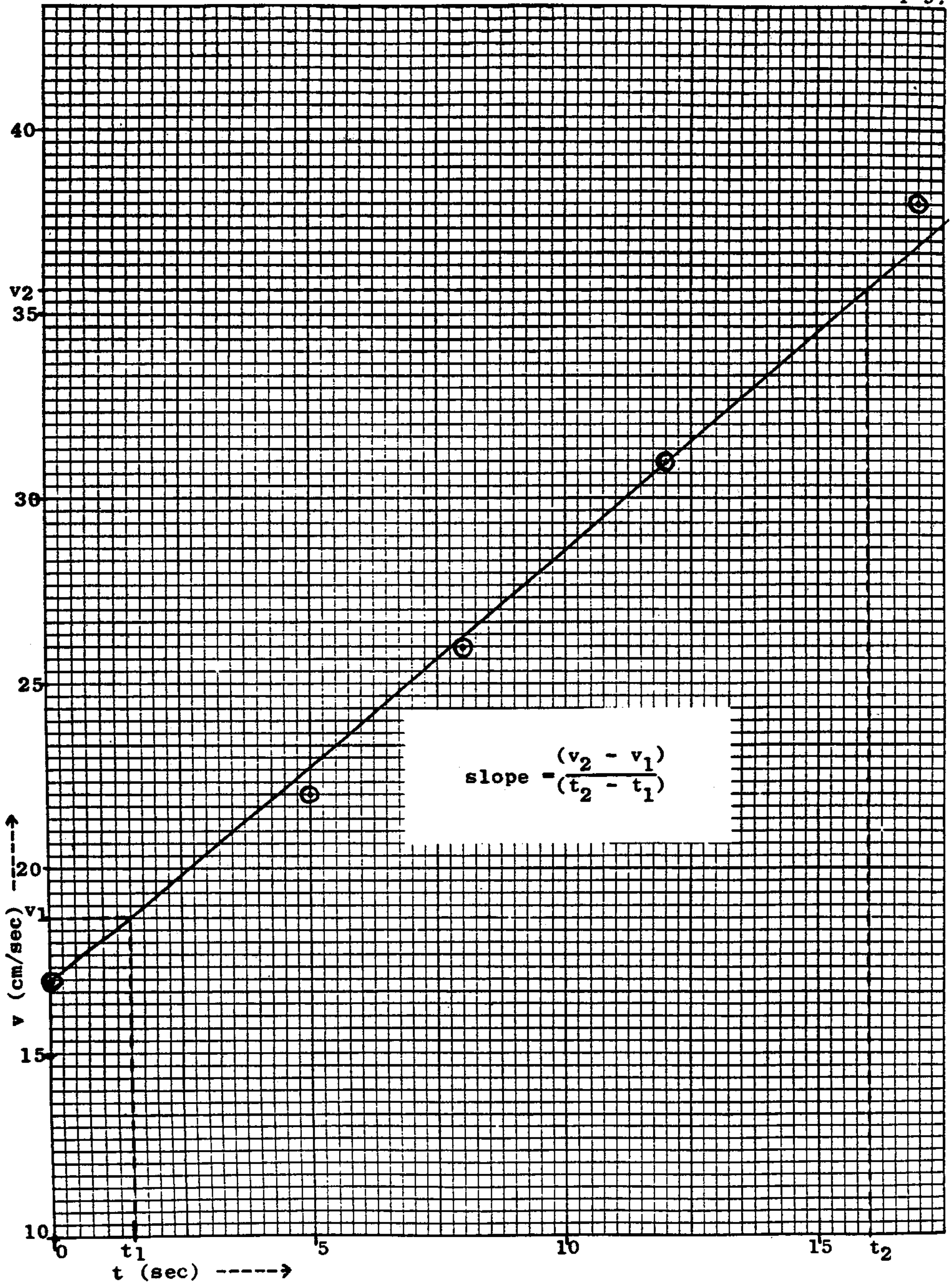
For convenience, we shall represent 1 cm/sec by 3 divisions.

Now we form the following table:

t (sec)	v (cm/sec)	$x = t - x_o$ sec	$y = v - v_o$ cm/sec	4*x divisions	3*y divisions
0	17	0	7	0	21
5	22	5	12	20	36
8	26	8	16	32	48
12	31	12	21	48	63
17	38	17	28	68	84

Now plot the graph as follows:

1. Mark the origin. Mark a few equidistant points along the x- and y-axes.
2. Write the physical quantities and the units along the x- and y-axes.
3. Plot the points by using the values in the last two columns of the above table.
4. Draw the 'best' curve such that it passes through as many points as possible, and, nearly as many points are above the curve as below it.


40
v2
35
30
25
20
v1
15
10
v (cm/sec)
0
t1
5
10
15
t2
t (sec)
slope = (v2 - v1)/(t2 - t1)

Instructions For Plotting A Graph By Using Microsoft EXCEL

Select the data for plotting the graph (values of x and y), for example, the values of V and I in the table for verification of Ohm's law.

Click on Chart Wizard in the first line of the menu bar.

Select chart type XY (scatter).

Press and hold to view sample.

Click on Finish.

Pull down Chart menu and click on location. Select sheet 3. The chart will be seen on sheet 3.

Pull down Chart menu and type in Chart title 'Ohm's Law Verification'.

Pull down Chart menu and click on chart options and select major and minor grid lines for X as well as Y.

Double click on X-axis to see Format axis. Click on scale and enter minimum, maximum, major unit, minor unit and 'value of (Y) axis crosses at' (enter minimum of X). Major unit should be (maximum-minimum)/5 and minor unit should be major unit/5.

Double click on Y-axis to see Format axis. Click on scale and enter minimum, maximum, major unit, minor unit and 'value of (X) axis crosses at' (enter minimum of Y). Major unit should be (maximum-minimum)/5 and minor unit should be major unit/5.

Pull down the File menu, select Print preview and print the graph.

Draw the 'best' straight line, select two points on the graph and perform the necessary calculations.

Experiment No. 1
D. C. Circuits

Objectives:

(a) To learn the use of a multimeter.

(b) To determine the resistance of a number of resistors by using (i) the color code, (ii) a multimeter and (iii) Ohm's law.

(c) To verify the laws of resistances in series and parallel.

Apparatus:

A power supply, resistors mounted on a circuit board, an ammeter, a multimeter.

Theory:

According to Ohm's law, the electric current in a metallic conductor is directly proportional to the potential difference between the ends of the conductor. Thus, if V (in volts) is the potential difference between the ends of the conductor PQ and the current in the conductor is I amperes, then

$$V = R\,I, \qquad (1)$$

where R (in ohms) is the constant of proportionality, known as the resistance of the conductor. Note that the resistance of a conductor depends on its temperature. As a conductor offers some resistance to the current, it is known as a resistor.

Power (in watts) consumed is given by

$$P = VI = I^2R \qquad (2)$$

There is a certain maximum power which can be safely applied to a resistor, and, correspondingly, a maximum safe current, I_m, which the resistor can have without overheating.

Equation (2) gives,

$$I_m = \sqrt{\frac{P}{R}} \qquad (3)$$

where P is the maximum power and R, the resistance of the resistor.

Most resistors used in the laboratory are 1-watt resistors.

Laws of resistors in series and parallel:

When two (or more) resistors are connected in series as shown in Fig. 1.1, their equivalent resistance is given by

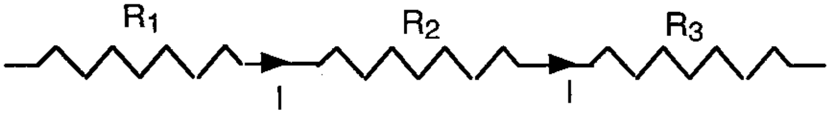


Fig. 1.1

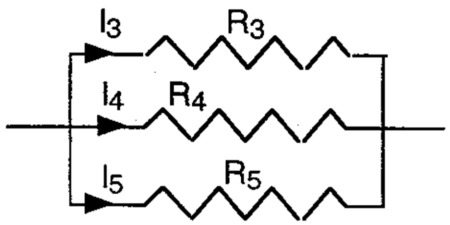


Fig. 1.2

$$R_S = R_1 + R_2 + R_3 \qquad (4)$$

In this case, the same current I passes through each resistor.

When two (or more) resistors are connected in parallel as shown in Fig. 1.2, their equivalent resistance is given by

$$\frac{1}{R_p} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} \qquad (5)$$

The equivalent resistance of the combination is equal to R_p. This implies that the combination can be replaced by a single resistor of resistance R_p.

In the case of a parallel combination, the potential difference across the resistors is the same, while the currents in the resistors are not equal unless the resistors have the same resistance. In any case, the sum of currents in the resistors R_3, R_4 and R_5 is equal to the total current I. The current in a given parallel branch is inversely proportional to the resistance of that branch.

Now let us consider the circuit shown in Fig. 1.3.

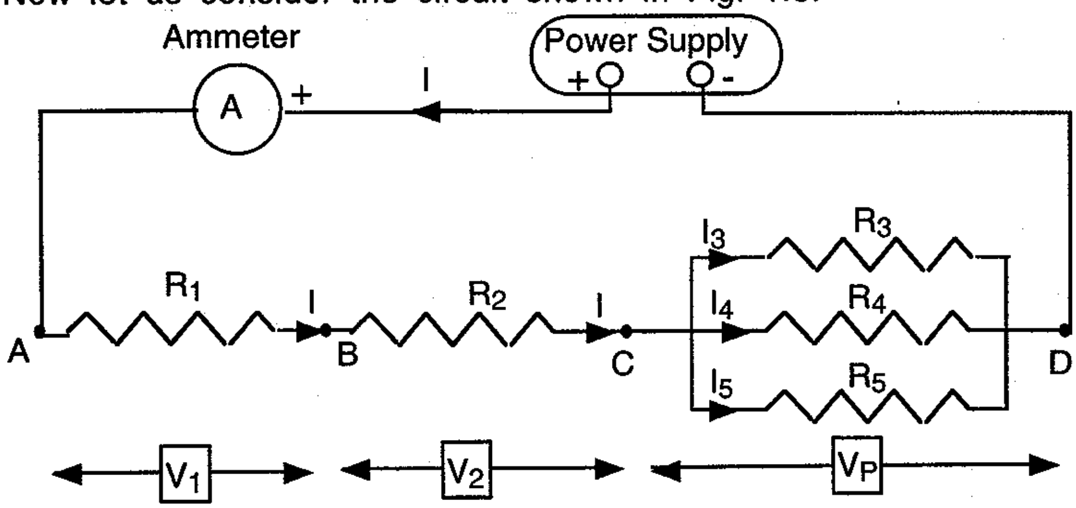


Fig. 1.3

The resistors R_3, R_4 and R_5 are in parallel. This parallel combination is in series with R_1 and R_2. The resistance of the parallel combination of R_3, R_4 and R_5 can be calculated by Eq. (5). Thus if R_p is the equivalent resistance of the parallel combination, then the total resistance of the circuit is given by

$$R_S = R_1 + R_2 + R_p \qquad (6)$$

Note that the total current in the circuit is I, which is also the current in R_1 and R_2. Further, the current I is distributed between the three parallel branches at the junction C. Thus

$$I = I_3 + I_4 + I_5 \qquad (7)$$

The potential difference across R_3 (or R_4 or R_5) is V_p, while the potential differences across R_1 and R_2 are V_1 and V_2, respectively. Hence the total potential difference between points A and D is given by

$$V = V_1 + V_2 + V_p \qquad (8)$$

Color Code:

The resistance of a resistor can be approximately determined from the colors of bands painted on the resistor. In general, there are four bands of different colors painted on the resistors.

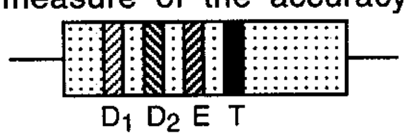
The color code is:

		Tolerance:	
0 - - Black	5 - - Green		
1 - - Brown	6 - - Blue	Gold	- - 5%
2 - - Red	7 - - Violet	Silver	- - 10%
3 - - Orange	8 - - Gray	No color	- - 20%
4 - - Yellow	9 - - White		

The color of the first band D_1 (which is nearest to an end of the resistor), gives the first digit of the resistance of the resistor. The color of the second band D_2 gives the second digit of the resistance of the resistor. The color of the third band E gives the exponent of 10 by which the number obtained by by using the colors of D_1 and D_2 should to be multiplied to obtain the resistance of the resistor.

Thus the resistance is given by $D_1D_2x10^E$.

The color of the fourth band T gives the tolerance of the resistor which is a measure of the accuracy of the resistance of the resistor.



D_1 -- red (2) E -- orange (3)

D_2 -- green (5) T -- silver (10%)

The resistance of the resistor shown in the above diagram is $25x10^3$ ohm (25000 ohm) and the tolerance is 10%.

Procedure:

Unit 1: Determination of resistance by color code and by multimeter:

(a) Choose 5 resistors from the circuit board and find their resistances and tolerance by using the color code.

(b) Familiarize yourself with the multimeter, set it to read resistance and measure the resistances of the 5 resistors by using the multimeter.

(c) Calculate the maximum safe current for each resistor by using Eq. (3). The current in each resistor should be kept below the maximum safe current for that resistor.
To ensure this, estimate the maximum safe voltage (V_{max}) by the following method:
If the lowest of the maximum safe currents for R_1 and R_2 is less than or nearly equal to the maximum safe currents for R_3, R_4 and R_5, the maximum safe voltage is given by
$V_{max} = I\,(R_1 + R_2 + R_p)$,
where I is the smaller of the maximum safe currents for R_1 and R_2.
Otherwise, $V_{max} = 3I'\,(R_1 + R_2 + R_p)$,
where I' is the lowest of the maximum safe currents for R_3, R_4 and R_5.
Make sure that the voltage of the power supply does not exceed V_{max}.
If you choose to skip the calculation of V_{max}, make sure that the current read by the ammeter (in Fig. 1.3) does not exceed the lowest of the maximum safe current of any resistor.

Unit 2: Laws of resistances in series and parallel:

(d) Make the connections as shown in Fig. 1.3. Remember that current must enter an ammeter or a voltmeter through the terminal marked + (red). In this experiment, the ammeter is used only to make sure that the current in the circuit remains constant during steps (e) and (f). Keep the voltage of the power supply below V_{max} or make sure that the current read by the ammeter (in Fig. 1.3) does not exceed the lowest of the maximum safe current of any resistor.

(e) Set the multimeter to read D.C. voltage. Measure V, the potential difference between points A and D; V_1, the potential difference between points A and B; V_2, the potential difference between points B and C and V_p, the potential difference between points C and D (that is, the across the parallel combination of R_3, R_4 and R_5).

(f) Set the multimeter to read D.C. current. Insert it between R_1 and R_2 (that is, in series with R_1 and R_2) and measure the total current I. Similarly, measure I_3, I_4 and I_5 by connecting the multimeter in series with =R_3, R_4 and R_5, respectively.

(g) To obtain more sets of data, change V (always keeping it below V_{max}) and repeat steps (e) and (f).

York College of The City University of New York

Physics II   Name:

Experiment No. 1: Pre-Lab Questionnaire

1. If two or more resistors are connected in series, ________________ in each resistor is ____________________.

2. If two or more resistors are connected in parallel, ________________ across each resistor is ____________________.

3. The colors of the first four bands on a resistor are orange, brown, red and silver. The resistance and tolerance of the resistor are:

4. What is meant by the maximum safe current for a resistor? Why should the current in a resistor should be kept less than the maximum safe current?

5. An ammeter should be connected so that the current ______________ ____

6. The reading of the ammeter in Fig. 1.3 should be kept constant during steps (e) and (f). Why?

Experiment No. 1

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Experiment No. 1
Data Sheet

Observations:

Record resistances in ohms, currents in mA and potential differences in volts.

Unit 1:

Resistor	By color code		Resistance by multimeter R(mm)	Percent diffe-rence*	Wattage of the resistor	Maximum safe current**
	Resistance R(cc)	Tolerance				
R_1						
R_2						
R_3						
R_4						
R_5						

* Between R(mm) and R(cc) by taking R(mm) as standard.

** Calculated by using R(mm).

Unit 2:

Voltage Readings	$V_{AD} = V =$	$V_{AB} = V_1 =$	$V_{BC} = V_2 =$	$V_{CD} = V_p =$
Current Readings	$I =$	$I_3 =$	$I_4 =$	$I_5 =$

Calculations:

V =	$V_t = V_1 + V_2 + V_p =$	Percent difference between V and V_t =
I =	$I_t = I_3 + I_4 + I_5 =$	Percent difference between I and I_t =

Resistor	Potential Difference	Current	Resistance R (ohm)	Percent Difference between R and R(mm)
R_1				
R_2				
R_3				
R_4				
R_5				

Combination	Potential Difference	Current	Equivalent Resistance (ohm)		Percent Difference
			Expt*	Formula**	
R_p (R_3, R_4 and R_5 in parallel)					
R_s (R_1, R_2 and R_p in series)					

* By using Ohm s law [Eq. (1)].

** By using the values of R(mm)'s.

Questions:

(Use the data obtained in the experiment to answer these questions.)

1. What would be the values of I_3, I_4 and I_5 if the total current I = 30 mA?

2. Use the value of the voltage of the power supply and the total current, and determine the total power supplied.

3. Fill out the following:

Resistor	Resistance	Current	Power
R_1			
R_2			
R_3			
R_4			
R_5			
		Total Power =	

4. What is the value of the maximum safe voltage?
   (Hint: See step (c) of the procedure.)

Experiment No. 2
Kirchhoff's Rules

Objective:

To verify Kirchhoff's rules.

Apparatus:

Two power supplies, resistors on a circuit board, an ammeter, a multimeter.

Theory:

In an electrical circuit, a junction where more than two currents meet is called a point. For example, in Fig. 2-1, A, B and C are points.

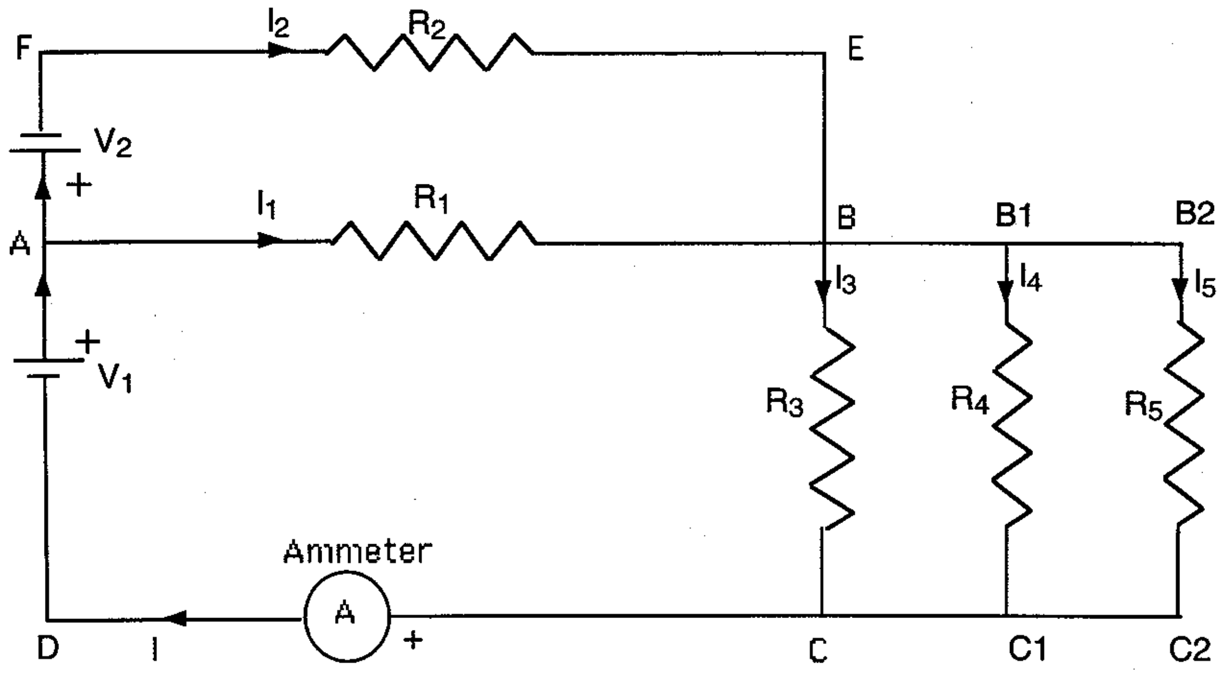


Fig. 2.1

Electrically B, B1, B2 and E are, essentially, one point because the connecting wires have negligible resistance. Similarly, C, C1, C2 and D are, in effect, one point because the connecting wires and ammeter have negligible resistance.

A loop in an electrical network, is defined as any closed path.

In Fig. 2-1, ABCDA, AFEBA, BB1C1CB, etc., are loops.

Kirchhoff's rules are:

Point rule: The algebraic sum of currents at any point of a circuit is equal to zero.

Thus

$$\Sigma I_i = 0. \qquad (1)$$

The currents in the direction towards the point are taken as positive and the currents leaving the point are taken to be negative.
For example, in Fig. 2-1,
for point A, $I - I_1 - I_2 = 0$,
and for point B, $I_1 + I_2 - I_3 - I_4 - I_5 = 0$.
Loop rule: The algebraic sum, over all the elements of a loop, of the products of current (I) in the resistance (or circuit element) and its resistance (R) is equal to the algebraic sum of emf's (E_i) in the loop. That is

$$\Sigma R_i I_i = \Sigma E_i \qquad (2)$$

For example, in Fig. 2-1,
for loop ABCDA, $I_1R_1 + I_3R_3 = V_1$,
for loop AFEBCDA, $I_2R_2 + I_3R_3 = V_1 - V_2$,
and for loop B1B2C2C1B1, $-I_4R_4 + I_5R_5 = 0$.
Note that here we have taken the clockwise direction to be positive for the currents and emf's.

Procedure:

Unit 1: Study of circuit containing a single voltage source:

(a) Use the multimeter to measure the resistances of all the resistors which are mounted on the circuit board. Calculate the maximum safe current for each resistor. Note that R_1 consists of two resistors in parallel.

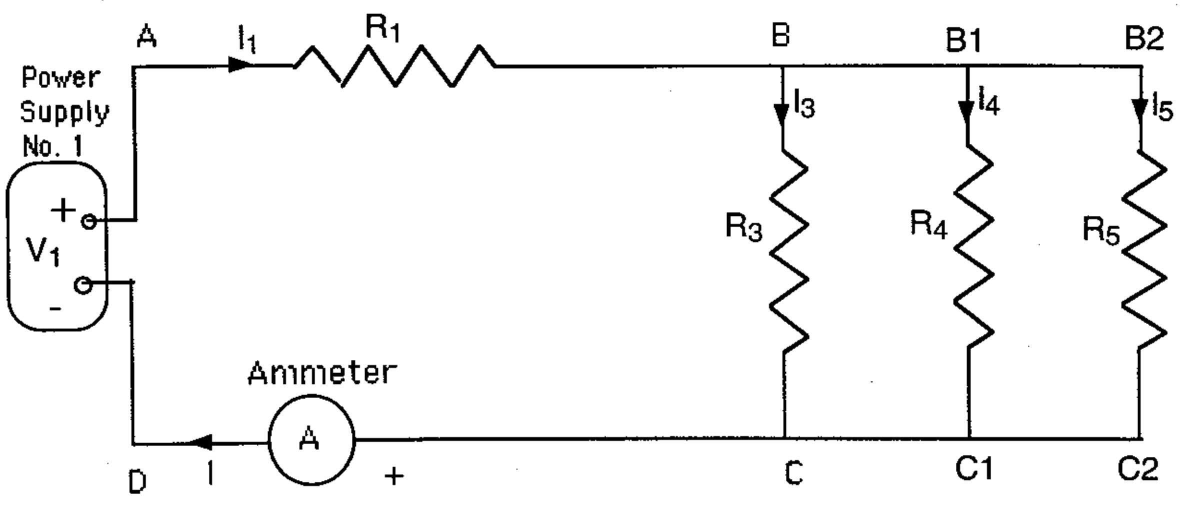


Fig. 2.2

(b) Make the circuit as shown in Fig. 2.2. Use the larger power supply in the circuit. Switch on the circuit.

(c) Adjust the output voltage of the power supply to about 100 volts. Record the readings of the ammeter and maintain it constant during step (d) of the procedure.

(d) Measure I_1 by connecting the multimeter in series with R_1. Measure I by connecting the multimeter between the points C and D. Connect the multimeter in series with R_3 and measure I_3. Similarly, measure I_4 and I_5 by connecting the multimeter in series with R_4 and R_5, respectively. Measure the output voltage of the power supply (V_1).
Consider the voltage and currents to be positive if they are in the directions of the arrows in Fig. 2.2.

(e) Repeat steps (c) and (d) by changing the value of V_1 to take more sets of data.

Unit 2: Study of circuit containing two voltage sources:

(f) Make the circuit as shown in Fig. 2.3 by adding the loop containing the second power supply and R_2 to the circuit of Unit 1.

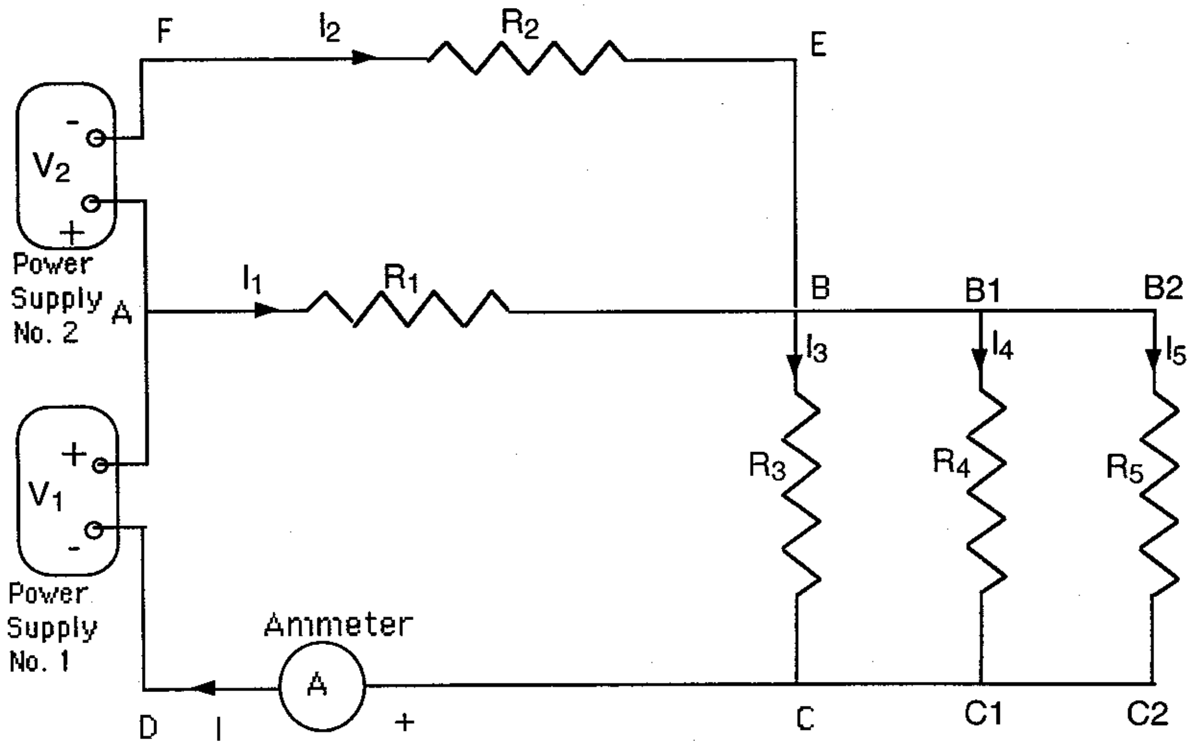


Fig. 2.3

(g) Adjust the output voltage of power supply No. 2 to about 30 volts. Take the reading of the ammeter and keep it constant during step (h) of the procedure.

(h) Measure the currents I, I_1, I_2, I_3, I_4 and I_5 by using the multimeter as in step (d). Measure the voltages V_1 and V_2 by using the multimeter.

(i) Repeat steps (g) and (h) by suitably changing V_1 and V_2 to obtain more sets of data. Remember that the current in each resistor should not exceed the maximum safe current for that resistor.

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Physics II Name:

Experiment No. 2: Pre-Lab Questionnaire

1. A point in an electrical circuit is defined as ______________________

   ____

   and a loop is defined as ______________________________________

2. Why do B, B1, B2 and E constitute essentially one point?

3. What is the purpose of connecting the ammeter A in Fig. 2.2 and Fig. 2.3?

4. How are different sets of readings obtained in this experiment?

Experiment No. 2

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Experiment No. 2
Data Sheet

Observations:

Record resistances in ohms, currents in mA and potential differences in volts.

Resistor	Resistance	Wattage of the resistor	Maximum safe current
R_1			
R_2			
R_3			
R_4			
R_5			

Unit 1:

Readings of currents and voltages should be recorded with proper signs.

Reading of ammeter (A) = (to be maintained constant)

V_1	I	I_1	I_3	I_4	I_5

Unit 2:

Reading of ammeter (A) = (to be maintained constant)

V_1	V_2	I	I_1	I_2	I_3	I_4	I_5

Calculations:

Unit 1:

Verification of Point Rule:

Point	ΣI_{in}	ΣI_{out}	Percent difference
B			
C			

Verification of Loop Rule:

Loop	Σ I R	ΣE	Percent difference
ABCDA			
AB1C1DA			
BB2C2CB			

Unit 1:

Verification of Point Rule:

Point	ΣI_{in}	ΣI_{out}	Percent difference
A			
B			
C			

Verification of Loop Rule:

Loop	Σ I R	ΣE	Percent difference
ABCDA			
AB1C1DA			
AFEBA			
AFEBCDA			
AFEBB2C2CDA			
AFEBB1C1CDA			

Questions:

(Use the data obtained in the experiment to answer these questions, where applicable.)

1. In unit 2, what is the current from the positive terminal of power supply no. 1 to point A (Fig. 2.3)?

2. In unit 2, if an ammeter is connected between points C and C1, what will be its reading?

3. In unit 1, what is the equivalent resistance between points A and D? (There are two methods of obtaining the answer to this question. Compare the answers obtained by the two methods.)

4. Can the resistance between points A and D (Fig. 2.2) be measured without disconnecting the power supply? Explain your answer.

5. In Fig. 2.1, why are points C, C1, C2 and D, in effect, are one point? Remember that there is an ammeter between points C and D.

Experiment No. 3
Galvanometer

Objective:

(a) To determine the resistance of a galvanometer.
(b) To verify that the deflection of a galvanometer is proportional to the current in it.
(c) To determine the current sensitivity and the voltage sensitivity of the galvanometer.

Apparatus:

A galvanometer, a power supply, a multimeter, two decade resistance boxes.

A galvanometer is an instrument used for detecting small electric currents and potential differences. Ammeters and voltmeters are basically galvanometers which have been suitably modified to measure currents and voltages, respectively. A pivoted-coil type galvanometer (Fig. 3-1(a)) consists of a coil of fine insulated copper wire, wound around a light metal frame and pivoted between two jeweled pivots P_1 and P_2. The coil moves in the magnetic field between the pole pieces (N, S) of the U-shaped magnet. When there is an electric current in the coil, a deflecting torque acts on it. The hair springs (H_1 and H_2) attached to the frame provide the restoring torque when the coil is deflected. The coil attains an equilibrium position when the deflecting torque becomes equal to the restoring torque.

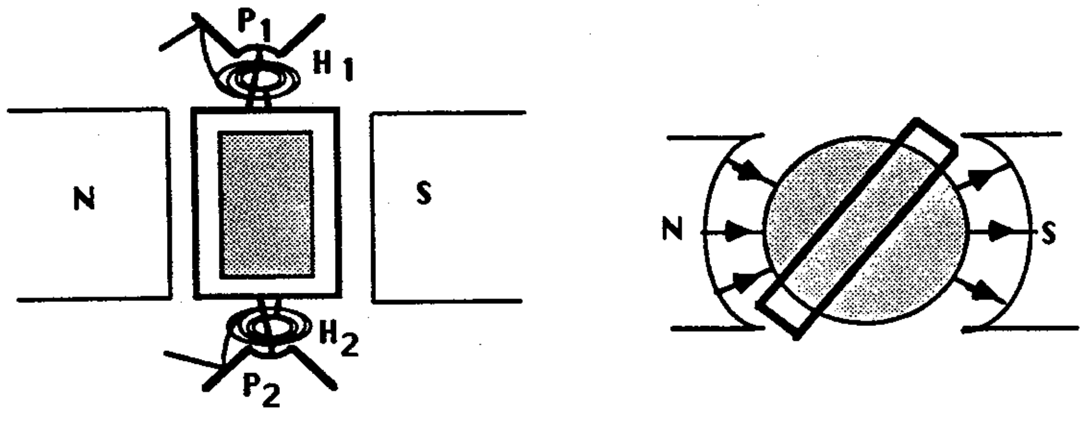

Fig. 3-1(a) Fig. 3-1(b)

31

The pole pieces of the magnet are concave. Thus the gap between them is cylindrical. A soft iron cylinder is placed centrally in the gap between the pole pieces. Thus the magnetic field in the air-gap is redirected normal to the curved surface of the cylinder. Consequently, the magnetic field acting on the current is parallel to the plane of the coil. This makes the deflection of the coil directly proportional to the current in the coil. When the metal frame on which the coil is wound moves in the magnetic field, eddy currents are induced in it and thus the oscillations of the coil are damped. A light aluminum pointer attached to the coil moves along the scale of the instrument. Sometimes, a large resistance is provided which can be connected in series with the coil to make it less sensitive.

Theory:

Resistance of a galvanometer:

In Fig. 3-2(a), let R_1 be the resistance connected in series with the galvanometer when the galvanometer shows full-scale deflection. Then, keeping the voltage (V) of the power supply unchanged, resistance R_{sh} is connected in parallel with the galvanometer by closing the switch S (Fig. 3-2(b)), and, thus the galvanometer deflection becomes about one-half of its maximum value. Next, the series resistance is changed from R_1 to R_2 so as to restore the deflection of the galvanometer to its original value (full-scale).

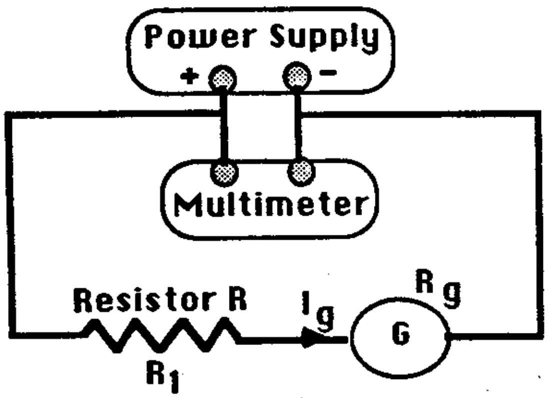

Fig. 3-2(a)

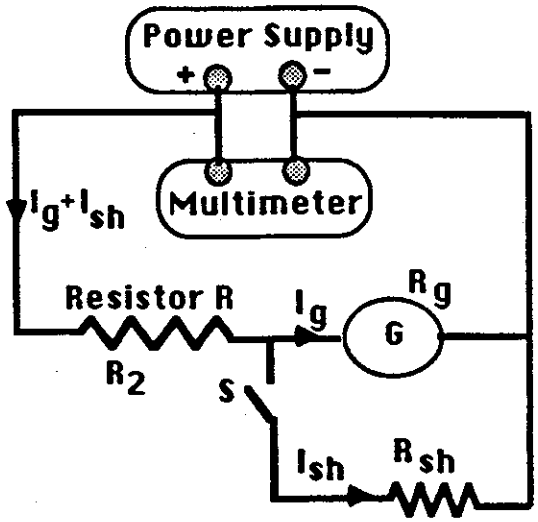

Fig. 3-2(b)

The current in the galvanometer is the same (I_g) in both cases because the deflection in both cases is full-scale. Applying Ohm's law to the circuit of Fig. 3-2(a), we get

$$V = I_g(R_1 + R_g), \quad (1)$$

where R_g is the resistance of the galvanometer.

Now, in Fig. 3-2(b), the potential difference across the galvanometer (G) is equal to the potential difference across the shunt resistance R_{sh}. Thus

$$I_g R_g = I_{sh} R_{sh}. \quad (2)$$

Further, $V = (I_g + I_{sh})R_2 + I_g R_g.$ (3)

By equating the right-hand sides of Eqs. (1) and (3), we get

$$I_g(R_1 + R_g) = (I_g + I_{sh})R_2 + I_g R_g,$$

or $I_g R_1 = (I_g + I_{sh})R_2,$

or $I_g R_1 = I_g R_2 + I_{sh} R_2.$

By substituting the value of I_{sh} from Eq. (2),

$$I_g R_1 = I_g R_2 + R_2 R_g I_g / R_{sh},$$

or $R_g = (R_1 - R_2)R_{sh}/R_2.$ (4)

Thus the resistance of the galvanometer can be determined from Eq. (4).

Current Sensitivity:

The current sensitivity of a galvanometer is defined as the current required to produce a deflection of 1 small division of the scale of the instrument.

Voltage Sensitivity:

The voltage sensitivity of a galvanometer is defined as the potential difference applied across its coil to produce a deflection of 1 small division of the scale of the instrument.

Evidently, if i_s is the current sensitivity of a galvanometer whose resistance is R_g, then the voltage sensitivity of the galvanometer is given by

$$v_s = i_s R_g.$$

If there are n divisions on the scale of the galvanometer, then a current ni_s will produce a full-scale deflection and thus the current for full scale deflection will be

$$I_g = n\, i_s\, .$$

Similarly, a potential difference of nv_s will produce a full-scale deflection.

Procedure:

(a) Study the construction and working of the galvanometer provided. Make sure that the pointer of the galvanometer is adjusted to zero. (Don't adjust the zero of the galvanometer. Request your instructor to adjust the zero, if necessary.)

Precaution:

Never switch on the circuit without including a large resistance in series with the galvanometer. The applied voltage should be kept low.

Unit 1: Determination of the resistance of the galvanometer:

(b) Make the circuit as shown in Fig. 3-2(b). Adjust the current limit to maximum and the voltage of the power supply to zero. Keep the switch S open. Note that when switch S is open, the circuit is the same as shown in Fig. 3-2(a). Set the resistance of the resistor R between 8,000 and 12,000 ohm. Now gradually increase the voltage of the power supply so that the deflection of the galvanometer becomes maximum. Record V and R_1, the value of the resistance of the resistor R.

(c) Keeping the voltage of the power supply V constant, insert R_s in parallel with the galvanometer by closing switch S. Adjust the value of R_s such that the deflection of the galvanometer is between 20 and 30 divisions. Now change the resistance of resistor R (which is connected in series with the galvanometer) such that the deflection of the galvanometer becomes maximum again. Record R_s and R_2, the value of the resistance of the resistor R. (If R_s is not a standard resistance, measure it with the multimeter.)

(d) Repeat steps (b) and (c) by changing R_1 by about 2000 ohms. Thus take two more readings. Note that V should be kept the same as in step (b) while taking each set of readings.

Unit 2: **Determination of current sensitivity and voltage sensitivity:**

(e) Make the circuit as shown in Fig. 3-2(a). Set the voltage of the power supply at zero and R_1, the resistance of resistor R at about 5000 ohm. Record R_1. Slowly increase the voltage so that the deflection of the galvanometer is 5 divisions. Record the deflection and the voltage in Table 2. Similarly, obtain the deflections of 10, 15, 20, 25, 30, 35, 40, 45 and 50 divisions by gradually increasing the applied voltage and recording it in Table 2. (Remember that the divisions and the units marked on the dial of the galvanometer are different.)

(f) Plot a graph between galvanometer deflection and current in the galvanometer.

(g) Calculate the current sensitivity of the galvanometer from the slope of the graph. Also calculate the voltage sensitivity of the galvanometer.

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Physics II Name:

Experiment No. 3: Pre-Lab Questionnaire

1. A galvanometer is used for ______________________________

____

2. When the coil of the galvanometer is deflected, the torque(s) acting on it is (are) ______________________________

____

3. The magnetic field in the air gap in which the coil moves is made radial by______________________________

____

4. The oscillations of the coil are damped by ____________________

____

5. In this experiment, the circuit should not be switched on without including a large resistance in series with the galvanometer and the applied voltage should be kept low because ____________________

____

6. The current sensitivity of a galvanometer is $1.2\text{x}10^{-4}$ A, its resistance is 45 ohm and it has 50 divisions on its scale. For the galvanometer, the voltage sensitivity, v_s = ______________________ and the current for full-scale deflection, i_g = ______________________

Experiment No. 3

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

Experiment No. 3
Data Sheet

Observations: Galvanometer Number:

Record resistances in ohms, currents in mA and potential differences in volts.

Unit 1: Determination of R_g:

Table 1

No.	V	R_1	R_{sh}	R_2	R_g

Average R_g =

Unit 2: Determination of current sensitivity and voltage sensitivity:

Number of divisions on the dial of the galvanometer =

Resistance R_1 =

Table 2

Number	Galvanometer Deflection (div)	V	$I = \frac{V}{R_1 + R_g}$
1	5		
2	10		
3	15		
4	20		
5	25		
6	30		
7	35		
8	40		
9	45		
10	50		

Calculations:

Coordinates of point 1 on the graph: divisions, mA

Coordinates of point 1 on the graph: divisions, mA

From the slope of the graph,

Current sensitivity =

Voltage sensitivity =

Current for full-scale deflection =

Potential difference for full-scale deflection =

Questions:

(Use the data obtained in the experiment to answer these questions, where applicable.)

1. What is meant by the current sensitivity of a galvanometer?

2. What is meant by the current for full-scale deflection of a galvanometer?

3. What is the voltage applied to the galvanometer (used in this experiment) when it is showing full-scale deflection?

4. What is the advantage of determining the resistance of a galvanometer by using Eq. (4) instead of Eq. (1)?

5. Will you obtain a straight line graph between n (number of divisions of deflection) and the corresponding current I if the soft iron cylinder (placed between the pole pieces of the magnet of the galvanometer) is removed? Explain your answer.

Experiment No. 4
Voltmeter and Ammeter

Objective:

(a) To convert a galvanometer into a voltmeter reading up to V volts and calibrate it.

(b) To convert a galvanometer into an ammeter reading up to I amperes and calibrate it.

Apparatus:

A galvanometer, a decade resistance box, a power supply, a multimeter, a piece of resistance wire and a cm scale.

Theory:

Converting a galvanometer into a voltmeter:

Let i_g be the current for full-scale deflection of the galvanometer and let R_g be the resistance of the galvanometer. Let R be the resistance which should be connected in series with the galvanometer coil (Fig. 4.1) to convert it into a voltmeter reading upto V volts. Then

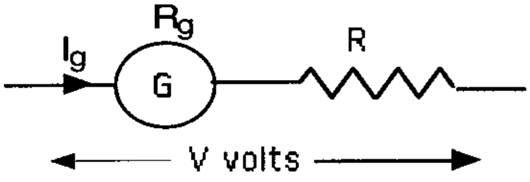

Fig. 4.1

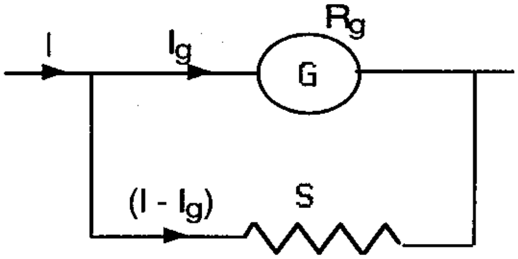

Fig. 4.2

$$V = I_g(R + R_g),$$

or $$R = \frac{V}{I_g} - R_g \qquad (1)$$

Note that I_g should be in amperes.

Conversion of a galvanometer into an ammeter:

To convert a galvanometer into an ammeter reading upto I amperes, a suitable small resistance S (known as shunt) is connected in parallel with its coil (Fig. 4.2). Thus

$$(I - I_g)S = I_g R_g$$

or $$S = \frac{I_g R_g}{(I - I_g)}. \qquad (2)$$

Remember that I and I_g should be in amperes.

Procedure:

Precaution: Do not switch on the circuit without including a large resistance in series with the galvanometer. Keep the applied voltage low.

Determination of the resistance of the galvanometer:

(a) If the resistance of the galvanometer is not known, determine it by the method described in Experiment No. 3.

(b) Record the number of units (not divisions) marked on the dial of galvanometer.

Determination of the current for full-scale deflection:

(c) Make the circuit as shown in Fig. 4.3. Adjust the current limit to maximum and the voltage of the power supply to zero. Adjust the resistance (R) of the decade box to about 10,000 Ω.

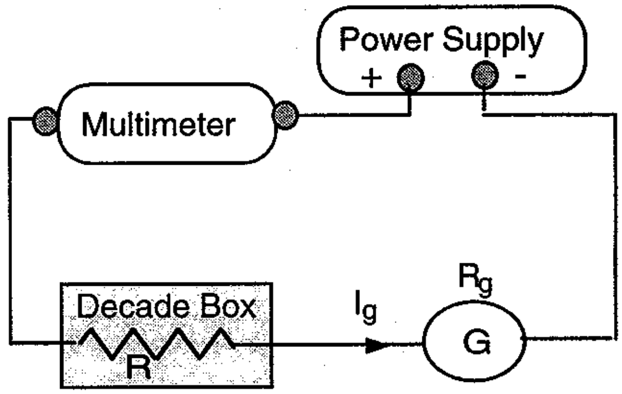

Fig. 4.3

(d) Now gradually increase the voltage of the power supply such that the galvanometer shows a full-scale deflection. Record the current for full-scale deflection as shown by the multimeter.

(e) To obtain two more readings of the current for full-scale deflection, decrease the voltage to zero, change R by about 1000 ohm and repeat step (d).

(f) Calculate the average value of i_g.

Conversion of the galvanometer into a voltmeter:

(g) Choose a range V (2.4, 1.6 or 1.2 volt) for the voltmeter.

(h) Calculate R by Eq. (1). To convert the galvanometer into a voltmeter connect a resistance R in series with the galvanometer.

Calibration of the voltmeter:

(i) Make the circuit as shown in Fig. 4.4. The multimeter should be set to read D.C. voltage. Adjust R to the value obtained in step (h).

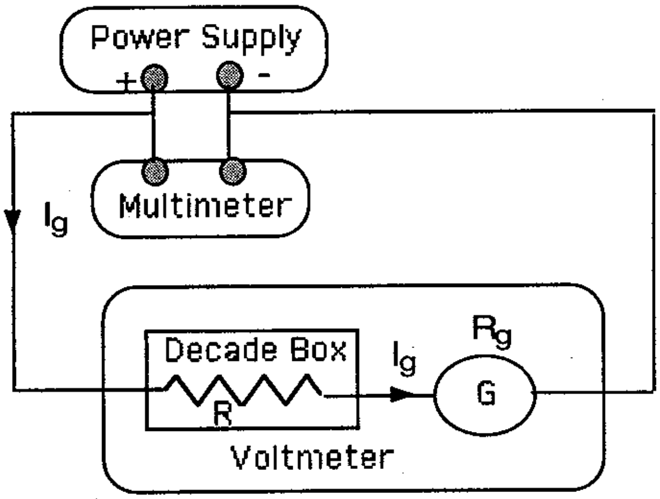

Fig. 4.4

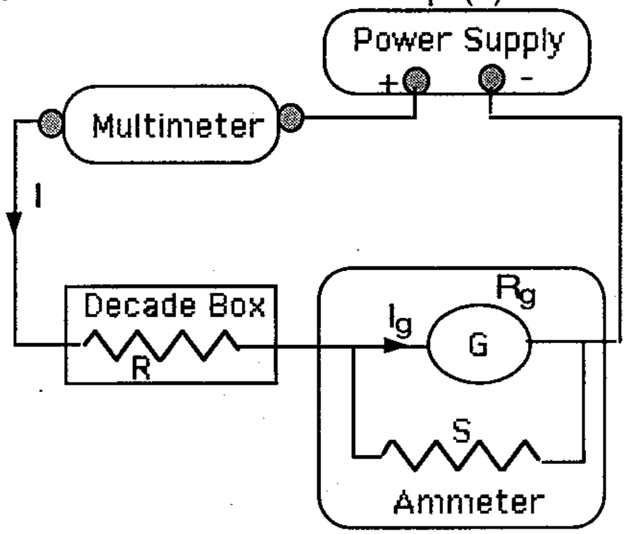

Fig. 4.5

(j) Adjust the voltage of the power supply and take the readings of the multimeter when the deflection of the galvanometer (converted into a voltmeter) is 20, 40, 60, 80 and 100 units.

(k) Plot the calibration curve.

Conversion of the galvanometer into an ammeter:

(l) Choose a range I (15, 20 or 25 mA) for the ammeter.

(m) Calculate S (the value of the shunt resistance) by Eq. (2). Find the length l of the shunt wire whose resistance is S. To convert the galvanometer into an ammeter, connect the shunt wire (of length l) across the terminals of the galvanometer so that the shunt wire is parallel with the galvanometer.

Calibration of the ammeter:

(n) Make the connections as shown in Fig. 4.5. The multimeter should be set to read D.C. current. Adjust the voltage of the power supply to zero and adjust R to about 2000 W.

(o) Adjust the voltage of the power supply such that the deflection of the galvanometer (converted by you into an ammeter) is 20, 40, 60, 80 and 100 units, and record the corresponding readings of the current shown by the multimeter.

(p) Plot the calibration curve.

York College of The City University of New York

Physics II   Name:

Experiment No. 4: Pre-Lab Questionnaire

1. In this experiment, different sets of readings for current for full-scale deflection are obtained by ______________________________

2. The resistance of a galvanometer is 45 ohm, the current for full-scale deflection is 1.2×10^{-4} A and it has 100 units marked on its scale.

   (a) Calculate the series resistance to convert it into a voltmeter reading up to 3 V. (b) Find the shunt resistance needed to convert it into an ammeter reading up to 20 mA. (c) If the resistance of the shunt wire is 0.03 ohm/cm, what should be the length of the shunt wire?

3. The range of a voltmeter is 3 V and it has 100 units on its scale. If it shows a deflection of 60 units, the applied potential difference is ____

4. The range of an ammeter is 25 mA and it has 100 units on its scale. If it shows a deflection of 60 units, the current in the ammeter is ____

Experiment No. 4

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Experiment No. 4
DATA SHEET

Observations: Galvanometer Number:

(Use the same galvanometer as you did in Expt. No, 3)

Number of units marked on the dial of the galvanometer
=

Resistance of the galvanometer R_g . . . . =

Current for full-scale deflection I_g . . . . (i) =

(ii) =

(iii) =

- - - - - - - - - - - - - - - -

Average I_g =

Calculation of series resistance R required to convert the galvanometer into a voltmeter reading upto V = volts:

$$R = \frac{V}{I_g} - R_g =$$

Calculation of shunt resistance S required to convert the galvanometer into an ammeter reading upto I = amperes:

$$S = \frac{I_g R_g}{(I - I_g)} =$$

Resistance per unit length of the shunt wire =

Length of the shunt wire ℓ . . . . =

Calibration of voltmeter:

No.	Deflection (in units)	V (multimeter)	V (voltmeter)
1	20		
2	40		
3	60		
4	80		
5	100		

Plot a calibration curve [V(voltmeter) vs. V(multimeter)].

Calibration of ammeter:

No.	Deflection (in units)	I (multimeter)	I (ammeter)
1	20		
2	40		
3	60		
4	80		
5	100		

Plot a calibration curve [I(ammeter) vs. I(multimeter)].

Questions:

1. Two resistors, R_1 = 400 ohms and R_2 = 600 ohms are connected in series with a power supply whose voltage V = 12 volts. What is the percent error in the potential difference across the 600-ohm resistor measured by using a voltmeter whose resistance is 1800 ohms? What will be the percent error if a voltmeter whose resistance is 6000 ohms is used?

2. Why should a voltmeter have large resistance? What is the resistance of the voltmeter obtained by you?

3. A circuit contains a power supply of voltage 2.4 volt and a resistance of 48 ohms. If an ammeter whose resistance is 2 ohms is used to measure the current in the circuit, what will be the percent error in current? What will be the percent error if a 0.002-ohm ammeter is used?

4. Why should an ammeter have negligible resistance? What is the resistance of the ammeter obtained by you?

5. Why is it necessary to calibrate an ammeter and a voltmeter?

Experiment No. 5
Resistivity And Temperature Coefficient of Resistivity

by Dr. E. M. Levin

Objective:

(a) To determine the resistivity of tungsten and to verify that resistivity is an intrinsic property of a material.

(b) To determine the temperature coefficient of resistivity of tungsten.

Apparatus:

25-, 40-, 60-, 75- and 100-watt incandescent lamps, a variable transformer (variac), 2 multimeters, lamp socket and connecting wires.

The filament of an incandescent lamp appears to be a simple coil to the naked eye. However, a closer look at reveals that the filament is a coiled coil. The thin filament is wound into the form of a thin coil and then a wider coil is made from the thinly coiled filament.

Theory:

The resistance R of a metal wire of length L and area of cross section A is given by

$$R = \rho \frac{L}{A} \qquad (1)$$

Here r is the resistivity of the material of the wire.

It should be noted that resistivity does not depend on the geometry (length or diameter of the wire). It only depends on the material of which the wire is made. Thus resistivity is called an intrinsic property of the material. As opposed to an intrinsic property, there are extrinsic properties which depend on the geometry of the sample.

Eq. (1) gives $\rho = R \frac{A}{L}$. Thus MKS units of ρ are ohm-m.

The resistivity ρ of a material strongly depends on the temperature. In general, it increases with temperature. Let ρ and ρ_o be the resistivity of a material at temperatures T and T_o, respectively. Over a moderate range of temperature,

$$\rho = \rho_o [1 + \alpha (T - T_o)] \qquad (2)$$

Here α is defined as the temperature coefficient of resistivity.

It should be remarked that Eq. (2) holds for moderate ranges of temperature. If the temperature range is large, higher order terms have to be considered.

For a given wire, R is directly proportional to r. Thus, from Eq. (2), we get

$$R = R_o [1 + \alpha (T - T_o)] \qquad (3)$$

Here R and R_o are the resistances of the wire at temperature T and T_o, respectively.

Solving for the temperature coefficient of resistivity, we get

$$\alpha = \frac{[R - R_o]}{[R_o(T - T_o)]} \qquad (4)$$

The temperature coefficient of resistivity of tungsten near room temperature is 0.0045 per C^o.

Procedure:

Unit 1: Determination of the resistivity of the material of the lamps at room temperature:

(a) Use the multimeter to measure the resistances of the lamps directly (without connecting them into the circuit).

(b) Record the room temperature.

Unit 2: Determination of the temperature coefficient of resistivity:

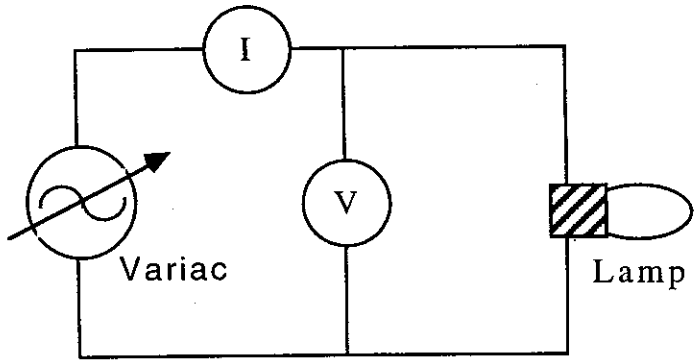

Fig. 6.1. An incandescent lamp powered by a variac.

(c) To measure the resistances of the filaments of the lamps at high temperatures (when they are connected in the circuit), we apply Ohm's law. Set up the circuit as shown in Fig. 1 including the 25-watt lamp in the circuit. Note that the multimeter measuring the current should be set to read AC current and that measuring the voltage, to read AC volts. Let your instructor check the circuit and then switch on the variac.

(d) Remember that the variac can supply voltage from 0 to 140 volts. The higher the voltage applied, the greater the power supplied which raises the temperature of the filament, and its brightness. Adjust the output voltage of the variac to 120 volts. Measure the current in the filament.

(e) Repeat the procedure with lamps of power 40, 60, 75 and 100 watts adjusting the output voltage of the variac to 120 V.

Follow the instructions contained in the data sheet for calculations and for plotting graphs.

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Physics II Name:

Experiment No. 5: Pre-Lab Questionnaire

1. The resistivity depends on ________________________________

   and ________________________________ but it does not depend

   on ________________________________.

2. Equation $\rho = \rho_o [1 + \alpha (T - To)]$ can be applied if

3. In this experiment, the resistances of the filaments of lamps at the operating temperatures are determined by

4. In this experiment, the variac is used for

Experiment No. 5

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

Experiment No. 5
DATA SHEET

Observations:

Unit 1: Determination of resistivity at room temperature:

Room Temperature =

Filament Data Table

[R_o (MM) is the resistance measured by using the multimeter.]

Lamp Wattage	Operating Temperature (T in C°)	Length of uncoiled filament (L in m)	Area of cross-section (A in m^2)	R_o(in ohm) (MM)
25	2290	0.56	$7.00x10^{-10}$	
40	2470	0.38	$8.56x10^{-10}$	
60	2550	0.53	$1.60x10^{-9}$	
75	2600	0.55	$2.23x10^{-9}$	
100	2650	0.58	$3.17x10^{-9}$	

Unit 2: Determination of current at operating temperature:

Lamp Wattage	Voltage Applied (V)	Current (A)
25	120	
40	120	
60	120	
75	120	
100	120	

Calculations:

Unit 1: Determination of resistivity at room temperature:

Lamp Wattage	Length of uncoiled filament (L in m)	Area of cross-section (A in m^2)	R_o(in ohm) (MM)	Resistivity ρ (in ohm-m)
25	0.56	7.00×10^{-10}		
40	0.38	8.56×10^{-10}		
60	0.53	1.60×10^{-9}		
75	0.55	2.23×10^{-9}		
100	0.58	3.17×10^{-9}		

Average, resistivity, ρ_m =

Percent error in ρ =

(The percent error is meaningful only if it is less than 20%)

Use the formula given on page Intro-4 of the Lab Manual to calculate the standard deviation.

No. (i)	ρ_i	$(\rho_i - \rho_m)$	$(\rho_i - \rho_m)^2$
1			
2			
3			
4			
5			

Standard Deviation in ρ =

Plot a graph of R against wattage on a linear graph paper.
Is resistance an intrinsic variable? Explain.

Plot a graph of ρ against wattage on a linear graph paper.
Is resistivity an intrinsic variable? Explain.

Unit 2: Determination of temperature coefficient of resistivity:
Use values of R_o from unit 1 to calculate α.

Lamp Wattage	V (volt)	I (amp)	Power V I (watt)	Resistance at operating temperature (R)	Temperature Coefficient (α) in $(C^o)^{-1}$
25					
40					
60					
75					
100					

Average value of α =

Percent error in α =

Questions:

1. What is meant by an intrinsic variable? An extrinsic variable?

2. Define resistivity. In some cases, the experimental value of resistivity differs from the standard value considerably. Why?

3. What is meant by temperature coefficient of resistivity?

4. Do the experimental values of power supplied agree with the rated wattage of the lamps? Explain your answer.

Experiment No. 7
Cathode Ray Oscilloscope

Objective:

(a) To study the working of a cathode ray oscilloscope.
(b) To measure a D.C. voltage, and, the amplitude and frequency of a waveform by means of a cathode ray oscilloscope.

Apparatus:

A cathode ray oscilloscope, a signal generator, a battery.

Description of a cathode ray oscilloscope:

A cathode ray oscilloscope is an instrument which is used to study rapidly varying currents and voltages, including pulses. It is also used to measure small time intervals, frequencies, phase differences, etc.

A cathode ray oscilloscope consists of a cathode ray tube (CRT) and the necessary electronic circuits, namely, power supplies, amplifiers, sweep generators, etc.

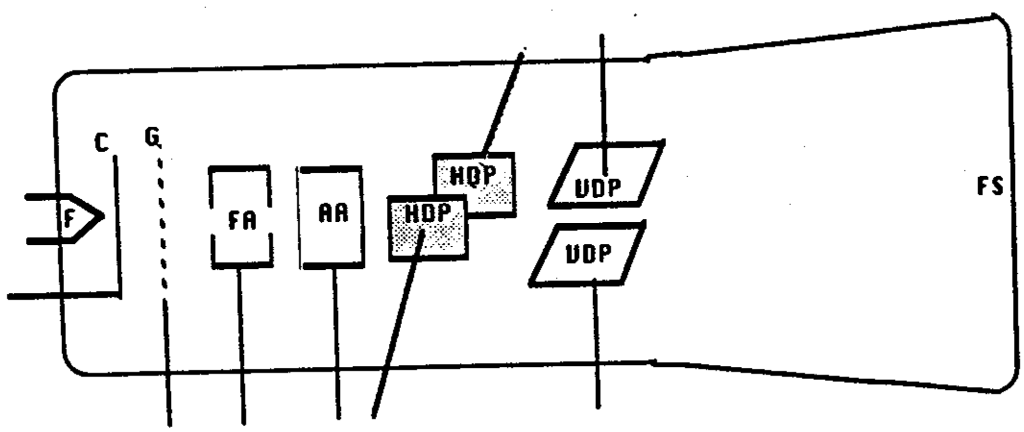


Fig. 7-1

A cathode ray tube (CRT), shown in Fig. 7-1, is a vacuum tube consisting of a filament F which is used to heat a cathode C that serves as a source of electrons. The electrons are accelerated by the accelerating anode AA. The grid G controls the number of electrons in the beam and thus the intensity of the display on the fluorescent screen FS can be varied.

The anode FA is used to focus the beam of electrons. Two pairs of plates, HDP and VDP, produce the deflection of the electron beam in the horizontal and vertical planes, respectively, when voltages are applied to them.

Built-in power supplies provide suitable voltages for the filament, grid, accelerating anode, focussing anode and to the circuits in the oscilloscope. Amplifiers are used to amplify small signals and to increase the vertical and horizontal deflections, if necessary.

There is a built-in sweep generator which can apply a 'saw-tooth' voltage (Fig. 7-2) to the horizontal deflection plates. Thus the electron beam is swept in the horizontal plane from left to right on the screen when the voltage increases from A to B (Fig. 7-2). Then the beam flies back to the left extremity and the sweep cycle is repeated over and over again. Obviously, the horizontal deflection of the beam is proportional to the elapsed time from the beginning of the sweep. The process of initiating the sweep is known as triggering. The sweep can be triggered or it can be run free.

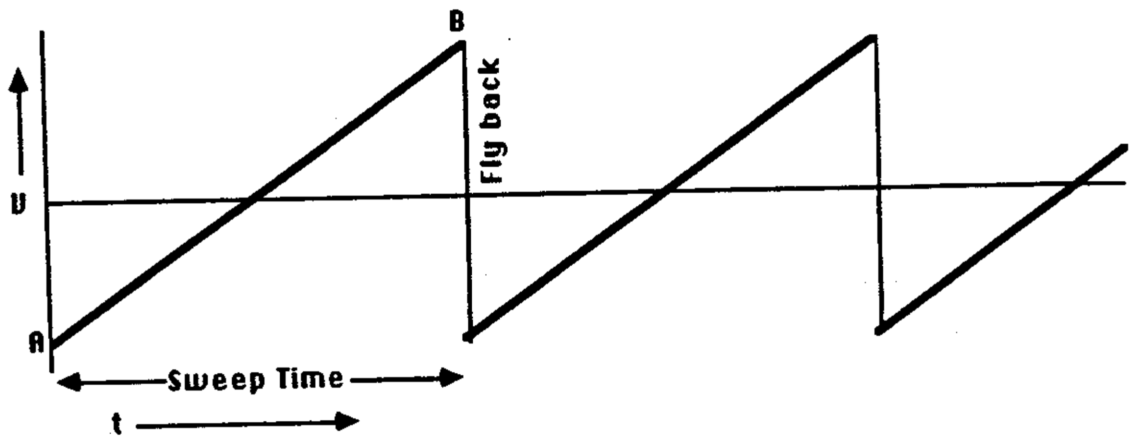


Fig. 7-2

Procedure:

A. Study the front panel of the oscilloscope and identify the various controls. The front panel of the oscilloscope is divided into five areas: CRT controls, CRT and LCD viewing area, UP-DOWN control area, function control area and potentiometer controls (Fig. 7-3).

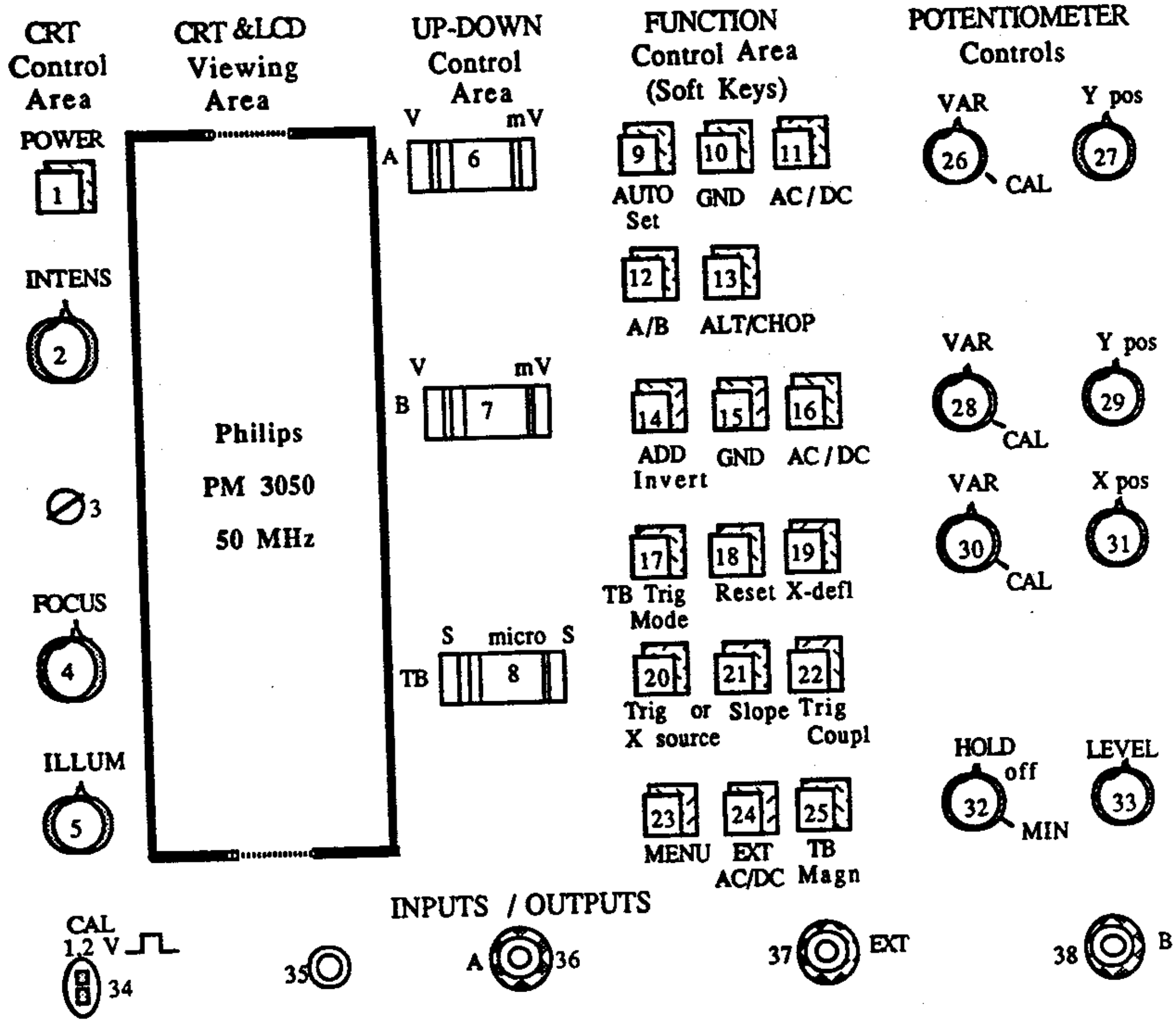
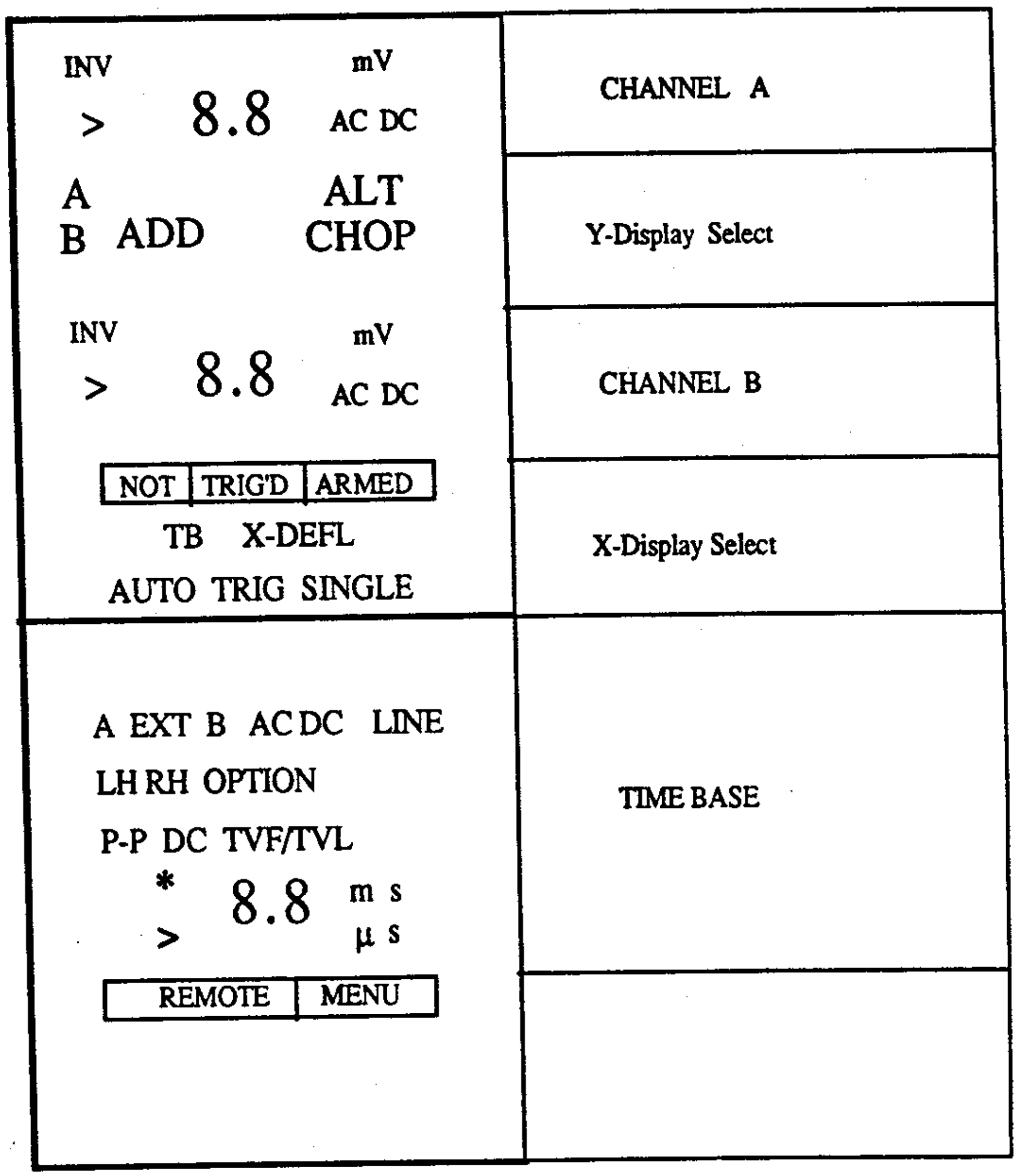


Fig. 7-3

The traces are displayed in the CRT viewing area while the LCD display area shows the different switch and control functions (Fig. 7-4).



Flashing > when not in CAL position

Fig. 7-4. Liquid Crystal Display

CRT control area has the following:

1. On-off power switch.

2. Intensity control to vary the intensity of the display.

3. Trace rotation control for aligning the trace with the horizontal graticule lines.

4. Focus control to focus the beams.

5. Illumination control to change the illumination of the graticule illumination.

The UP-DOWN control switches permit selection of volt or millivolt per division settings of channel A (switch 6) and channel B (switch 7), and the time per division setting(switch 8).

The softkeys (9 through 25) enable the possibility to select several functions with a single pushbutton in sequential order. To obtain the correct function, a given softkey is pressed repeatedly until the desired indication is displayed in the LCD viewing area.

For example, by sequentially pressing softkey 12, the following functions are obtained:

Channel A ----> Channel A and B ----> Channel B -----> No Channel

Then the above sequence starts over again.

The functions of the softkeys and potentiometer controls are summarized in Table 1.

INPUT / OUTPUT JACKS:

Socket CAL 1.2 V (34 in Fig. 7-3) provides 1.2 V peak-to-peak (P-P) square wave voltage.

Socket EXT (37 in Fig. 7-3) is for connecting the external trigger signal.

BNC sockets A and B (36 and 38 in Fig. 7-3) are for channel A and channel B inputs.

Table 1. Functions of Softkeys and Potentiometer Controls

Softkey No	Function
9	To set V/div and time/div to an optimal display.
10(15)	To interrupt the channel A (channel B) input signal by connecting the attenuator to the ground.
11 (16)	AC or DC coupling of channel A (channel B) input.
12	Selection of the vertical display modes, channel A or channel B or both.
13	Selection of alternate (ALT) or chopped (CHOP) display modes. In the ALT mode, the display switches over from one channel to the other at the end of each sweep. In the CHOP mode, the display switches from one channel to another at a fixed frequency.
14	Switch for inversion of channel B polarity and for the addition or subtraction of channels A and B.
17	TB (time base) trigger mode, AUTO free-run or TRIG mode or SINGLE. AUTO implies that the time base generator is free-running 100 ms after the last trigger pulse. TRIG implies that the time base starts upon a signal derived from a selected trigger source (A, B, EXT or LINE).
18	Reset knob for the time base. ARMED is displayed in single mode and NOT TRIG'D in AUTO and TRIG modes.
19	X DEFL to select horizontal deflection mode, namely time base or X DEFL.
20	Selection of time base trigger source, A, A B, B, EXT or LINE.
21	Trigger slope selection of the input signal.
22	Selection for the time base trigger coupling.
23	Selection for learning mode, MENU or previous settings. When MENU is displayed, by pressing any softkey, the functions behind that key are displayed at intervals of 0.5 second.
24	Input coupling for EXT input as a trigger source for the time base.
25	Time base magnification by a factor of 10.
26 (28)	Variable control channel A (channel B). CALibrated position is selected when fully clockwise.
27 (29)	Y-position control channel A (Channel B).
30	Variable control for time base. CAL position is selected when fully clockwise.
31	X-position control.
32	HOLD OFF control determines the hold off time between the time base sweeps. When the control is fully clockwise, the hold off time is minimum.
33	LEVEL control to control the level of the trigger point at which the time base starts.

B. Initial Turn-on Procedure:

1. Set the intensity to minimum. Switch on the power.

2. Set POSITION (horizontal and vertical) to midrange.

3. Set DISPLAY to channels A and B and display mode to CHOP.

4. Set Volt/Division (of A and B) to 5 volt/division and set both vertical verniers (26, 28) to calibrated (CAL) position.

5. Set time/division to 50 ms/div, set horizontal vernier (30) to CAL position and time base trigger mode to AUTO or TRIG.

6. Set trigger source to A.

7. Adjust INTEN and FOCUS to obtain two sharp horizontal lines.

C. Calibration of Volt/Div Switch:

1. Do the initial turn-on procedure.

2. Set DISPLAY to A and volt/div (A) to 0.2 volt/div. The vertical division must be in CAL position.

3. Set channel A vertical coupling to AC and connect CAL 1.2 V signal to channel A +INPUT jack. A square wave will appear on the screen. Adjust volt/div (A), if necessary.

4. Measure the vertical peak-to-peak height of the square wave display. If this height is n divisions, then 0.2n volt is the measured value of the signal. Calculate the percent error in your measurement.

5. Measure the horizontal length (AB) of the square wave signal. This is equal to one-half of the length of the waveform. If the length is m divisions and the time/div switch is set to t, then the period of the wave is 2 mt. Calculate the frequency of the CAL 1.2 volt signal.

D. Measurement of a DC Voltage:

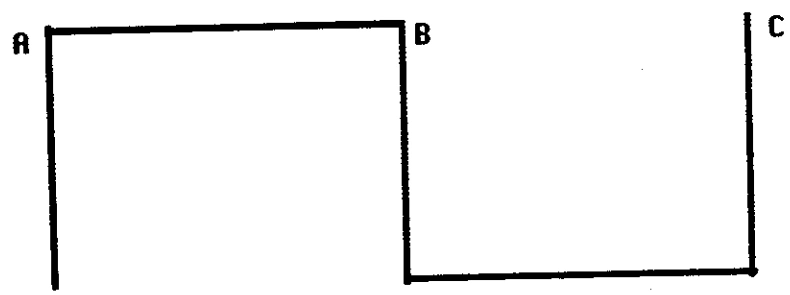
1. Do the initial turn-on procedure. Set DISPLAY to A and channel A volt/div to 0.2 volt/div.

2. Set channel A vertical coupling to DC and connect the voltage to be measured (a dry cell) to the channel A input jacks.

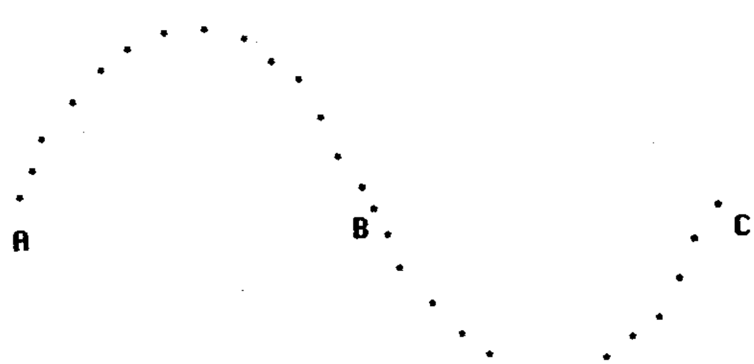
3. The trace will be observed to move up or down by changing the channel A vertical coupling from AC to DC. Adjust channel A volt/div, if necessary.
   If the trace goes off the screen, adjust the Y-position (of channel A) after disconnecting the DC source.

4. Measure the vertical displacement of the trace. Reverse the polarity of the external DC voltage and measure the displacement of the trace again.

5. Calculate the voltage ($V_{observed}$) and the corrected voltage (V_{cor}) by using the results of procedure C



Square Wave



Sine Wave

E. Determination of Amplitude and Frequency of a Sine Wave:

1. Perform the initial turn-on procedure.

2. Set DISPLAY to channel A and channel A volt/division to 0.2 volt/div. Both the vertical and horizontal verniers should be in CAL position.

3. Set channel A coupling to AC.

4. Switch on the signal generator. Adjust the RMS (root-mean-squared or effective) voltage of the sine wave to 1 volt and frequency to about 500 hertz (Hz). Set LOAD (of signal generator) to INT.

5. Apply the sine wave signal to channel A input jacks. Adjust the volt/div (of channel A), time/div, and the horizontal and vertical positions to display about one sine wave on the screen.

6. Change the trigger mode to TRIG and observe the change in the waveform. Change it back to AUTO, if necessary.

7. Change the SLOPE setting and observe the change in the waveform.

8. Rotate the trigger LEVEL knob and observe the changes in the waveform.

9. Measure the vertical separation (p) between the crest and trough of the sine wave. If the volt/div is v, then the peak-to-peak voltage is vp volt. The amplitude is one-half peak-to-peak voltage. Finally, measure the wavelength (the distance between the points A and C) of the sine wave.

York College of The City University of New York

Physics II   Name:

Experiment No. 7: Pre-Lab Questionnaire

1. A cathode ray oscilloscope is used for ______________________________

____

____

2. The function of A/B soft key is ______________________________

____

3. In the ALT mode, the display consists of ______________________________

____

4. In the CHOP mode, the display consists of ______________________________

____

5. A saw-tooth voltage is used for ______________________________

____

6. A flashing > indicates that ______________________________

____

7. A waveform displayed on the screen of a CRO can be modified by

____

____

____

Experiment No. 7

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

Experiment No. 7
DATA SHEET

Observations:

Unit 1:Calibration of Volt/Division Switch:

Peak-to-peak voltage of the calibrated square wave (V_t) =

Setting of Volt/Division switch (V) =

Setting of Time/Division switch (t) =

Vertical height of the square wave display (n) =

Length of one-half waveform (m) =

Unit 2: Measurement of a D. C. voltage:

Setting of Volt/Division switch (V') =

Vertical position of trace when the dry cell is connected =

Vertical displacement of trace when the polarity of the dry cell is reversed and coupling is changed from OFF to D.C. =

Unit 3: Determination of the amplitude and frequency of a sine wave:

Setting of Volt/Division switch (V") =

Setting of Time/Division switch (t") =

RMS voltage of the sine wave (V_i) =
(read from signal generator)

Frequency of the sine wave (f_i) (read from signal generator) =

Peak-to -peak height of the sine wave display (p) =

Length of one waveform of sine wave display (L) =

Calculations:
Unit 1:

Peak-to-peak voltage of square wave (experimental) $V_e = V\,n$ =

Percent error = $100(V_e - V_t)/V_t$ =

Period of the square wave = 2 mt =

Frequency of the square wave = 1/period =

Unit 2:

Average displacement of the trace with the dry cell, d =

Experimental value of D.C. voltage = d V' =

By using the percent error in calibration obtained in Unit 1,

corrected value of the D.C. voltage =

Unit 3:

Experimental value of peak-to-peak voltage of the sine wave = p V" =

Amplitude of the sine wave =

Corrected amplitude of the sine wave (V_p) =
(obtained by using the percent error determined in Unit 1)

Observed RMS voltage of the sine wave $V_o = \frac{V_p}{\sqrt{2}}$ =

Percent difference between V_i and V_o =

Period of the sine wave = Lt" =

Frequency of the sine wave f_o =

Percent difference between f_i and f_o =

Questions:

1. Why do we see a continuous curve on the screen of the oscilloscope when the electron beam is swept?

2. What is meant by triggering?

3. What is the function of the MODE switch?

4. What is the function of the DISPLAY switch?

5. Why should the horizontal and/or vertical vernier be in CAL detent position while taking readings?

6. Distinguish between peak-to-peak voltage, amplitude and RMS voltage of a sine wave signal.

Experiment No. 8
Time Constant Of An RC Circuit

Objective:

(a) To determine the time constant of an RC circuit.
(b) To determine the capacitance of a capacitor.

Apparatus:

A cathode ray oscilloscope, a signal generator, a capacitor and a decade box.

Theory:

(a) *Time constant of an RC circuit:*

Consider the circuit of Fig. 8-1. When the switch S is in position 1, the voltage V_O is applied to the capacitor C and resistor R (which are in series). Initially, at time t equal to zero, the charge on the capacitor and the potential difference between its plates are zero, and, thus the voltage applied to charge the capacitor is maximum (V_O).

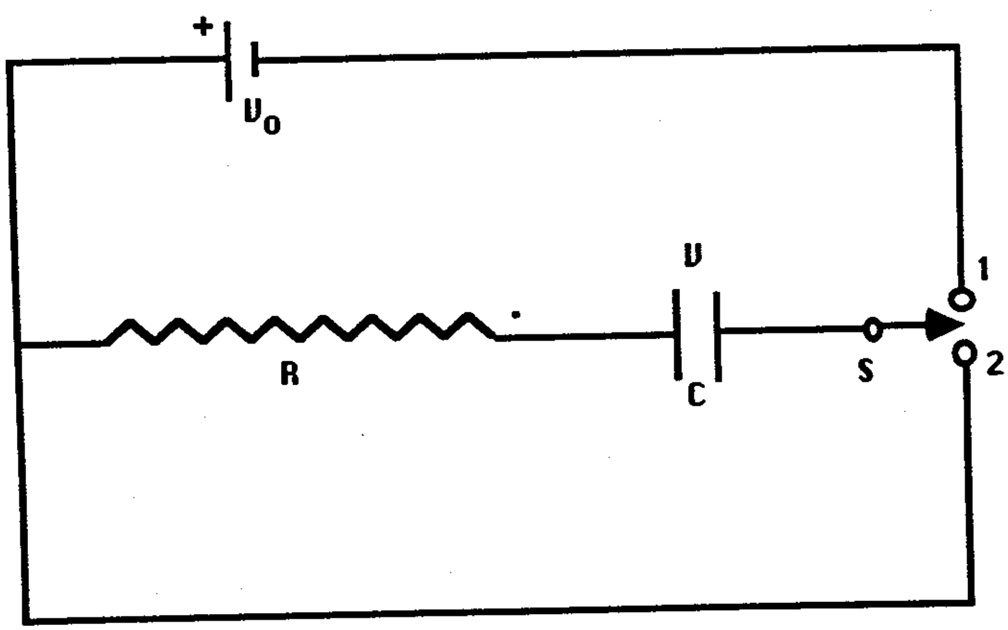


Fig. 8-1

Hence the rate of charging of the capacitor (current in the circuit) is maximum. As the charge on the capacitor increases, the voltage of the capacitor (V) rises. Thus the effective voltage charging the capacitor decreases to $(V-V_o)$. Therefore, the rate of charging the capacitor decreases. Finally the charge on the capacitor becomes maximum (q_o) and V becomes equal to V_o.

The charge on the capacitor at time t is given by

(Process of charging)

$$q = q_o(1 - e^{-t/RC}), \tag{1}$$

and, the voltage

$$V = V_o(1 - e^{-t/RC}). \tag{2}$$

Now if the switch S is changed to position 2, the capacitor will start discharging. Initially, the charge on the capacitor is maximum (q_o) and the potential difference between its plates is maximum (V_o). Therefore, the rate of discharging at time $t = 0$, is maximum. As the charge on the capacitor and V decreases, the rate of discharging decreases. Finally, the charge on the capacitor is reduced to zero.The charge on the capacitor and the voltage V at time t are given by

(Process of discharging)

$$q = q_o e^{-t/RC}, \tag{3}$$

and,

$$V = V_o e^{-t/RC}. \tag{4}$$

The curve showing V or q plotted against time [Eqs. (1) and (2)] for the process of charging is shown in Fig. 8-2. Note that V (or q) approaches V_o (or q_o) asymptotically

The curve showing V or q plotted against time [Eqs. (1) and (2)] for the process of discharging is shown in Fig. 8-3. Note that V (or q) approaches zero asymptotically.

Now if we substitute t = RC in Eqs. (1) and (2), we get

$$q = q_o(1 - 1/e) = 0.63q_o,$$

and $$V = V_o(1 - 1/e) = 0.63q_o.$$

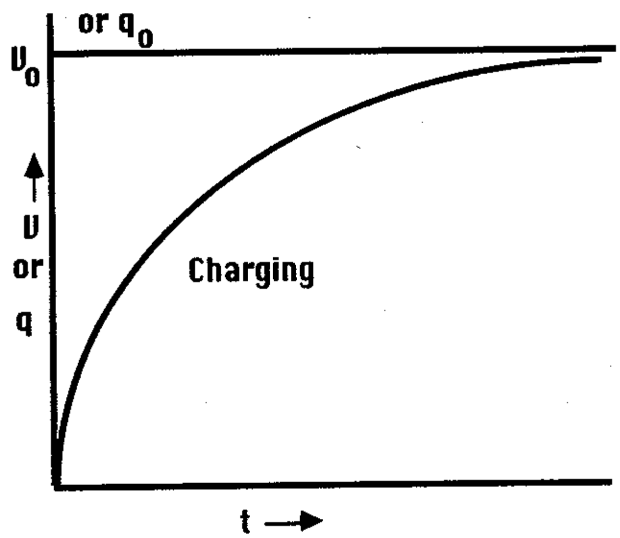


Fig. 8-2

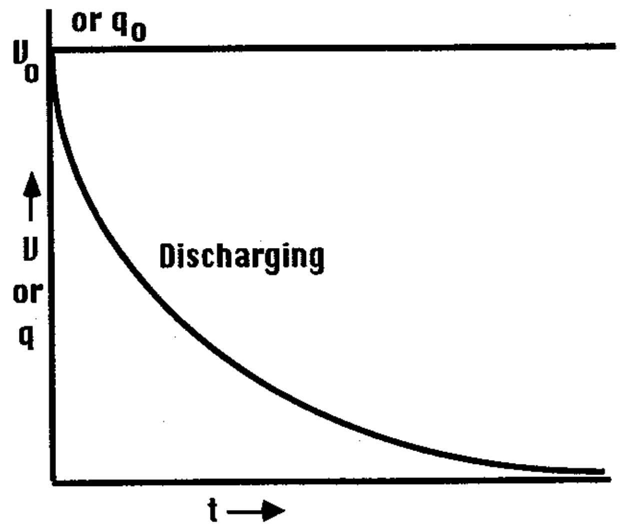


Fig. 8-3

Thus we define the time constant t_c (= RC) as the time taken by the capacitor to acquire 63% of the maximum charge.

Further, if we substitute t = RC in Eqs.(3) and (4), we get

$$q = q_o/e = 0.37q_o,$$

and $$V = V_o/e = 0.37V_o.$$

Therefore, the time constant t_c is also the time taken by the capacitor to lose 63% of the initial charge (q_o).

Now Eq. (2) gives

$$V = V_o - V_o e^{-t/RC}, \quad \text{or} \quad V_o - V = V_o e^{-t/RC}.$$

Taking log to base e, we get, (for the process of charging)

$$\ln(V - V_o) = \ln V_o - t/RC. \qquad (5)$$

Eq.(5) is like $y = m x + b$,
where $y = \ln(V - V_o)$, $x = t$, $m = -1/RC$ and $b = \ln V_o$.

Thus if a graph of $\ln (V - V_o)$ is plotted against t, the time constant RC can be determined from the slope of the graph.

Similarly, Eq.(4) gives, (for the process of discharging)

$$\ln V = \ln V_o - t/RC. \qquad (6)$$

Thus, in this case, the time constant RC can be obtained from the slope of ln V vs. t graph.

Instead of plotting a graph between ln V [or $\ln(V - V_o)$] against t on an ordinary graph paper, we can plot V [$(V - V_o)$] against t on a semi-log graph paper and obtain straight line graph(s).

Let (t_1, V_1) and (t_2, V_2) be the coordinates of two points on the graph of Eq.(6) (which is for the process of discharging). Then

$$\ln V_1 = \ln V_o - t_1/RC,$$

and

$$\ln V_2 = \ln V_o - t_2/RC.$$

By subtracting one equation from the other, we get

$$\ln V_1 - \ln V_2 = (t_2 - t_1)/RC,$$

or

$$\ln (V_1 / V_2) = (t_2 - t_1)/RC,$$

or

$$RC = (t_2 - t_1)/[\ln (V_1 / V_2)]. \qquad (7)$$

Thus the time constant $RC = (t_c)$ can be calculated.

The time constant can also be determined by taking the coordinates of two points on the $\ln(V - V_o)$ vs. t graph and by using Eq.(5).

In this experiment, instead of a DC voltage and a mechanical switch, if we apply a square wave signal to the capacitor as shown in Fig. 8-4, the capacitor will be charged when the voltage is Vo (segment AB of the square wave in Fig. 8-5) and the charge on the capacitor will decay when the voltage of the square wave is zero (segment CD in Fig. 8-5). The oscilloscope traces of the charging and discharging of the capacitor have also been shown in Fig. 8-5.

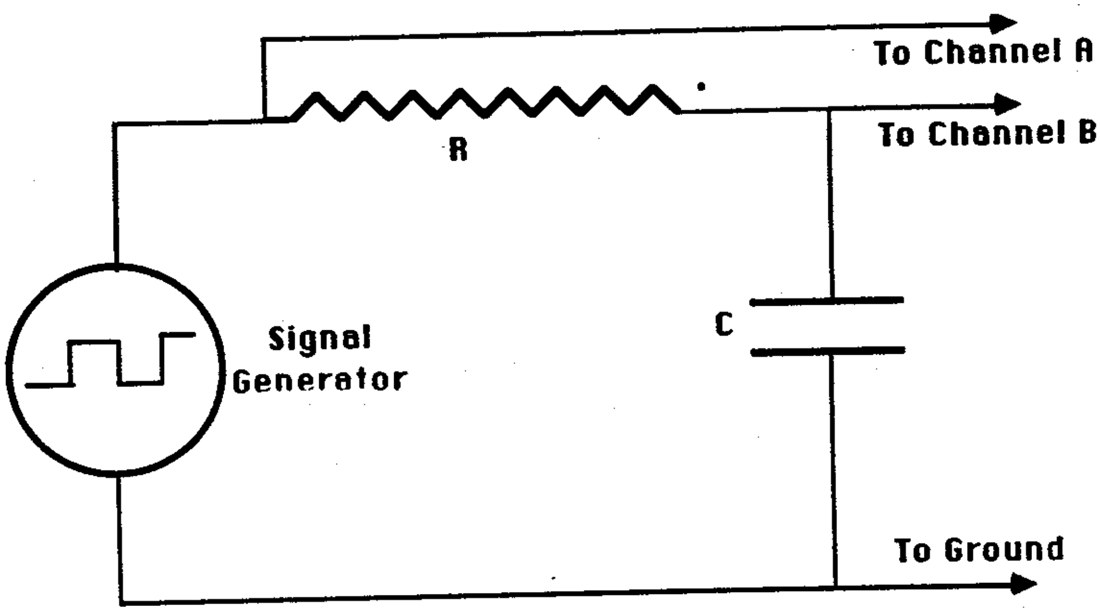


Fig. 8-4

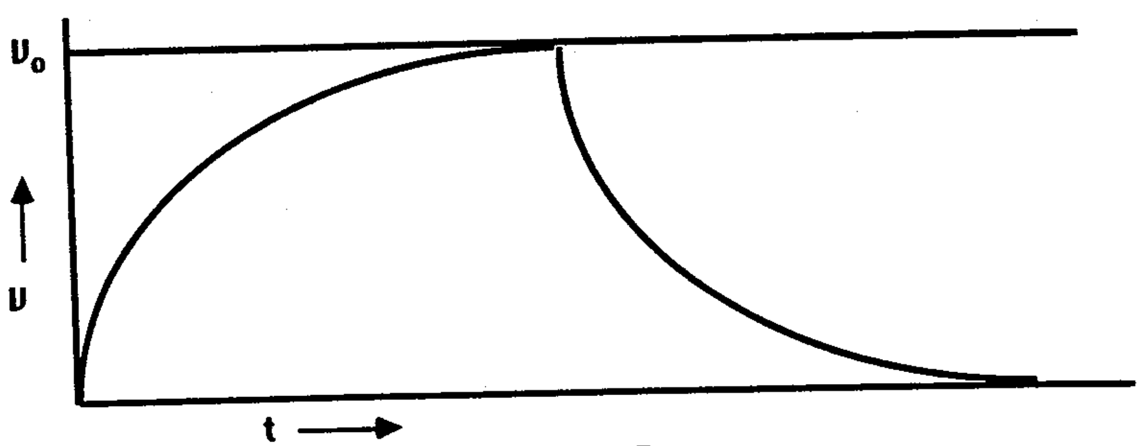


Fig. 8-5

It should be noted that if the period (T') of the square wave is less than t_c (=RC), then the capacitor will start discharging before it has sufficient time to acquire the maximum charge (q_o). In this case, the

CRO display will appear as shown in Fig. 8-6 and the asymptotic rise and decay of the voltage and charge will be missing from the display. On the other hand, if T' is much larger than t_c (=RC), then the display will appear as shown in Fig. 8-7. Why?

In this experiment, the frequency of the square wave should be adjusted to obtain the display shown in Fig. 8-5

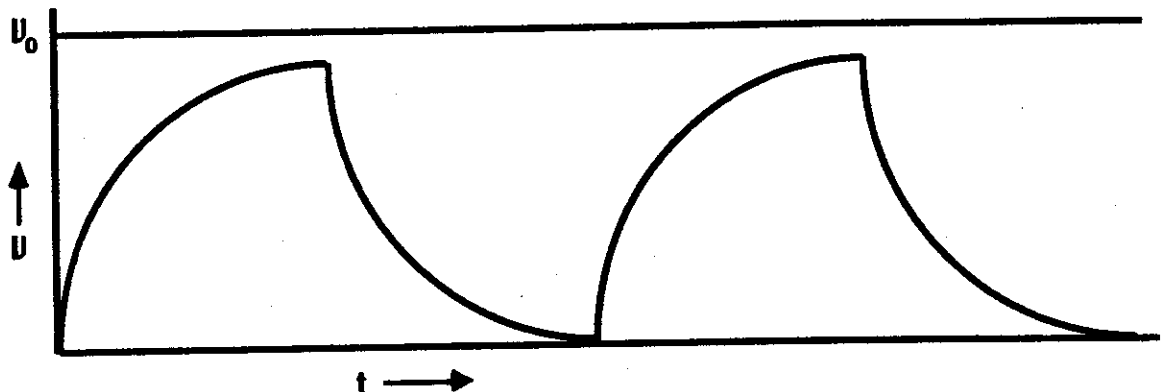


Fig. 8-6

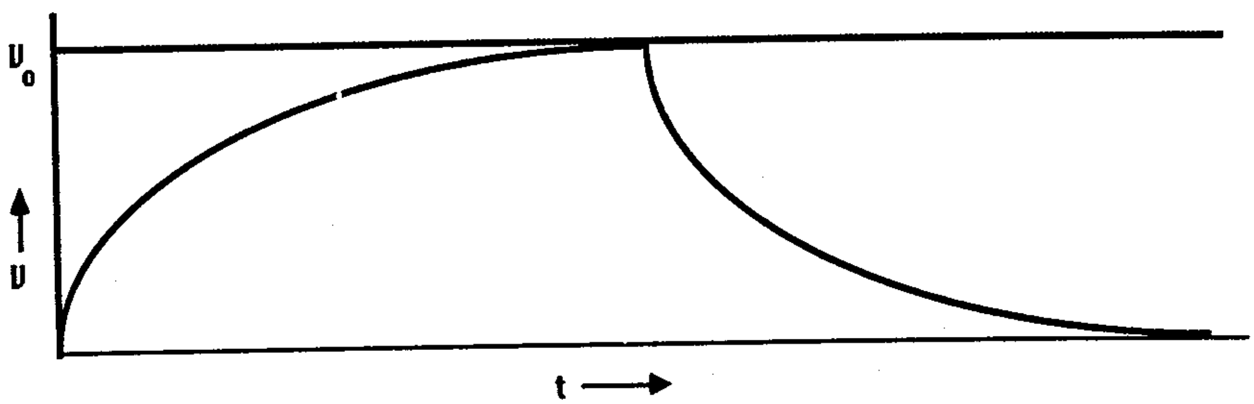


Fig. 8-7

(b) *Determination of the capacitance of a capacitor:*

For the process of discharging of a capacitor, according to Eq.(4),

$$V = V_0 e^{-t/RC}.$$

If we measure $T_{1/2}$ which is the time for the charge q to become $q_0/2$, (that is the time for $V = 0.5\ V_0$), we get

$$0.5\ V_O = V_o e^{-(T_{1/2}/RC)},$$

or $$e^{-(T_{1/2}/RC)} = 2,$$

or, by taking the log to the base e,

$$T_{1/2} = RC \ln 2. \tag{8}$$

Thus, for a given capacitor (C = constant), a graph of $T_{1/2}$ vs. R will be a straight line and C can be calculated from the slope of the graph. Let the coordinates of two points on this graph be (R_1, T_1) and (R_2, T_2). Then

$$T_1 = R_1 C\ (\ln 2),$$

and $$T_2 = R_2 C\ (\ln 2).$$

By subtracting one equation from another and solving for C, we get

$$C = (T_2 - T_1)/[(\ln\ 2)(R_2 - R_1)] \tag{9}$$

Procedure:

Unit 1: Determination of the Time Constant of an RC Circuit:

(a) Make the circuit as shown in Fig. 8-4.

(b) Perform the initial turn-on procedure for the oscilloscope.

(c) Set trigger mode to AUTO, set vertical coupling of channels A and B to AC and SLOPE to +. Set volt/div of channels A and B to 0.2 volt/div. Display mode can be CHOP or ALT.

(d) Set the frequency of the square wave to about 100 Hz and the output voltage to about 0.5 volt.

(e) Adjust R to about 8000 ohms and C to about 0.1 microfarad.

(f) Record R, C, f, volt/division and time/division.

(g) Measure the height of the decay curve above the threshold (shown in Fig.8-8) for 5 or 6 different instants of time. These readings can be obtained by changing the x-position suitably. (Ask your instructor, if necessary.)

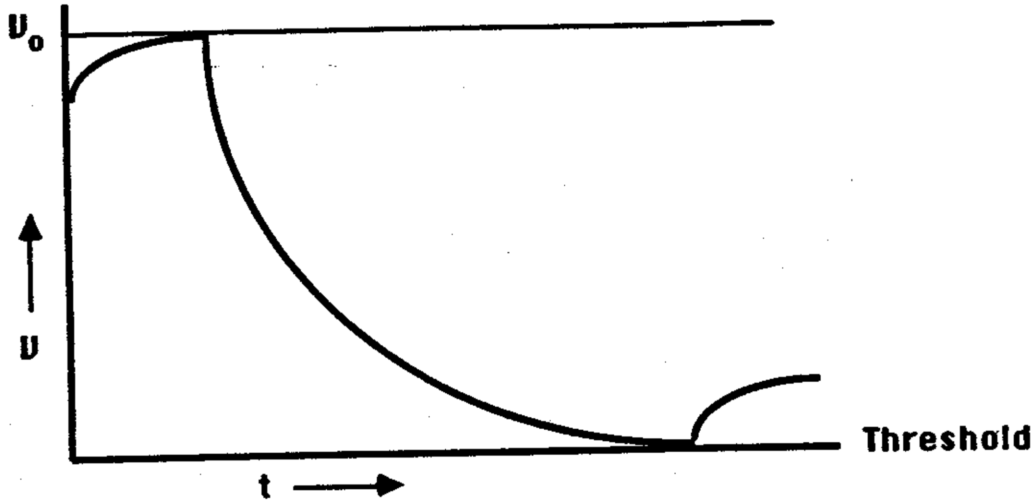


Fig. 8-8

(h) Plot the height of the decay curve against time on a two-cycle semi-log graph paper.

Unit 2: Determination of the capacitance of a capacitor:

(i) Insert the unknown capacitor in the circuit.

(j) Set R to about 4000 ohms and make the necessary adjustments to obtain the display as shown in Fig. 8-8.

(k) Record R, time/division and $T_{1/2}$ (the time at which $V = V_o/2$).

(l) Repeat steps (j) and (k) with 4 or 5 different values of R.

York College of The City University of New York

Physics II   Name:

Experiment No. 8: Pre-Lab Questionnaire

1. The function of the signal generator in this experiment is ____________

____

____

2. In this experiment, time/division control must be (need not be) in the calibrated position because ______________________________

____

3. In this experiment, volt/division control must be (need not be) in the calibrated position because ______________________________

____

4. If R = 45000 ohm and C = 1.2 μF, the time constant is ______________

____

5. Two ways of obtaining a straight line graph by using the data of the table on page 8-1D are: ______________________________

______________________________ and ____________________

____

Experiment No. 8	
Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	
Title:	
Objective:	
Theory/Formulas:	

DATA SHEET

Observations:

Unit 1: Time constant of an RC circuit:

Peak-to-peak height of the square wave =

Frequency of the square wave =

Resistance R =

Capacitance C =

Setting of Volt/Div switch (Channel A) =

Setting of Volt/Div switch (Channel B) =

Setting of Time/division switch (vernier set at CAL detent) =

Reading of threshold (in divisions) =
(Y-coordinate of the lowest point of the decay curve)

Readings of time and position of the decay curve along the ordinate:

No.						
Time* (divisions)						
Position** (divisions)						

* X-coordinate of the points selected on the decay curve.
** Y-coordinate of the points selected on the decay curve.

Unit 2: Capacitance of a capacitor:

Standard value of capacitance (if known) =

No.	R	Time/div	$T_{1/2}$	
			Divisions	Seconds

Calculations:

Unit 1:

Plot a graph of V vs. T on a 2-cycle semi-log graph paper.

Theoretical value of time constant RC =

Coordinates of two points on the V vs. T graph:

Experimental value of time constant =

(Do not forget to convert divisions into sec.)

Percent difference between the theoretical and experimental values of time constant =

Unit 2:

Coordinates of two points on $T_{1/2}$ vs. R graph:

C=

If the standard value of C is known, calculate the percent error in C.

Questions:

1. A student had a display as shown in Fig. A. How can it be changed to the form shown in Fig. B? What will happen if the SLOPE is changed from + to - when the display was as shown in Fig. B? Draw the display.

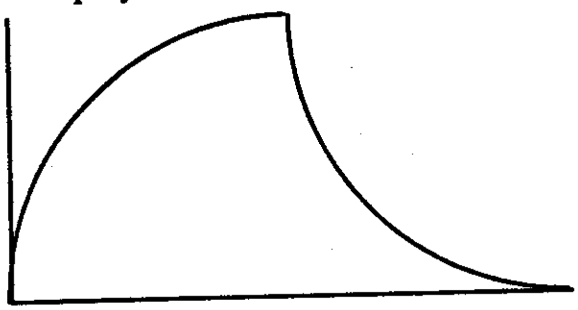


Fig. A

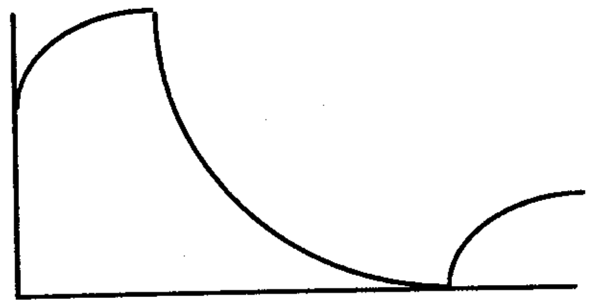


Fig. B

2. What was the voltage on the capacitor in reading number 2 of the first table? What was the charge on the capacitor at that time?

3. Why does the rate of discharge of the capacitor decrease with time?

4. A student forgot to record the volt/div (or he/she forgot to set the vertical verniers in CAL detent). Can he/she find the time constant and C from his/her data? Explain.

Experiment No. 9
ALTERNATING CURRENT CIRCUITS I

Objective: To study the AC circuits containing (a) a resistor and a capacitor, and (b) a resistor and an inductor.

Apparatus: A cathode ray oscilloscope, a decade resistance box, a capacitor, an inductor, a multimeter, a signal generator.

Theory:

(a) AC circuit containing R and C:

Let an external alternating voltage of effective value V_E and frequency f be applied to the circuit containing R and C (as shown in Fig. 1). The effective current I in the circuit obeys the equation

$$V_E = Z I . \qquad (1)$$

Here Z is the impedance of the circuit and it is given by

$$Z = \sqrt{R^2 + X_C^2} , \qquad (2)$$

where

$$X_C = \frac{1}{2\pi f C} . \qquad (3)$$

X_C is known as the capacitive reactance.

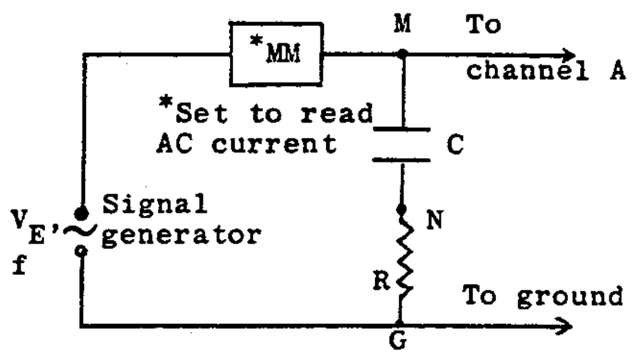


Fig. 1

The current leads the voltage in this case, by an angle ϕ given by (see Fig. 2)

$$\tan \phi = X_C/R. \qquad (4)$$

If we multiply Eq. (2) by I, we get

$$I Z = \sqrt{(IR)^2 + (IX_C)^2} ,$$

or

$$V_E = \sqrt{V_R^2 + V_C^2} . \qquad (5)$$

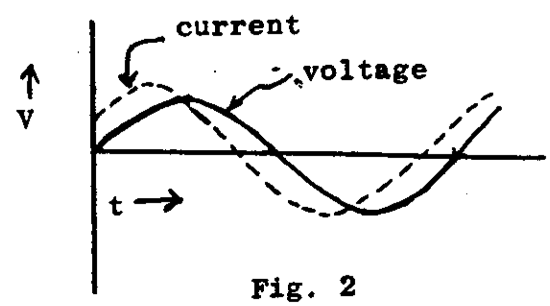


Fig. 2

(b) AC circuit containing R and L:

If an external voltage of effective value V_E and frequency f is applied to the circuit containing R and L (as shown in Fig. 2), then the effective current I is given by Eq. (1) and the impedance Z of the circuit is given by

$$Z = \sqrt{R^2 + X_L^2}, \qquad (6)$$

where

$$X_L = 2\pi f L. \qquad (7)$$

X_L is called the inductive reactance.

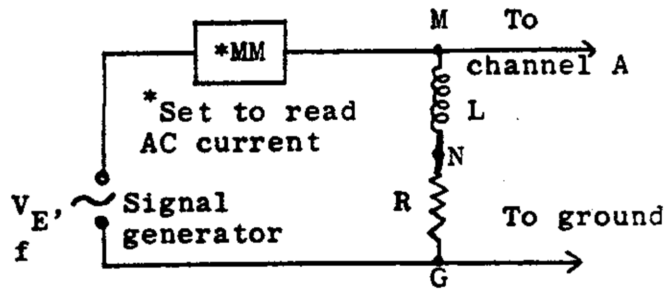


Fig. 3

In this case, the voltage leads the current by an angle ϕ given by (see Fig. 4)

$$\tan\phi = X_L/R. \qquad (8)$$

Further, Eq. (6) gives

$$V_E = \sqrt{V_R^2 + V_L^2}. \qquad (9)$$

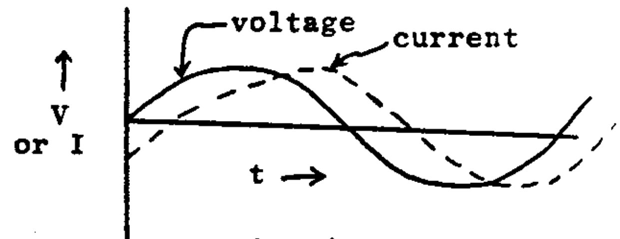


Fig. 4

In this experiment, the oscilloscope is used to determine V_E, V_C(or V_L) and ϕ. V_E, V_C (or V_L), V_R and I are also measured by using the multimeter. It should be noted that the multimeter gives the effective values of AC voltages and currents. However, instantaneous values of voltages are displayed on the screen of the oscilloscope. The peak-to-peak values ($2V_p$) of AC voltages are measured from the display and then the formula

$$\text{effective } V = V_p/\sqrt{2} \qquad (10)$$

is employed to obtain the effective values. The peak-to-peak voltage is shown in Fig. 5(given on the next page).

To determine the phase difference ϕ, the half wavelengths A_1A_2 and B_1B_2 (Fig. 6) are measured and their average x is calculated. Then A_1B_1 and A_2B_2 are measured and their average δx is found. Now one-half wavelength corresponds to a phase difference of 180°. Thus the phase difference between the two waves is given by

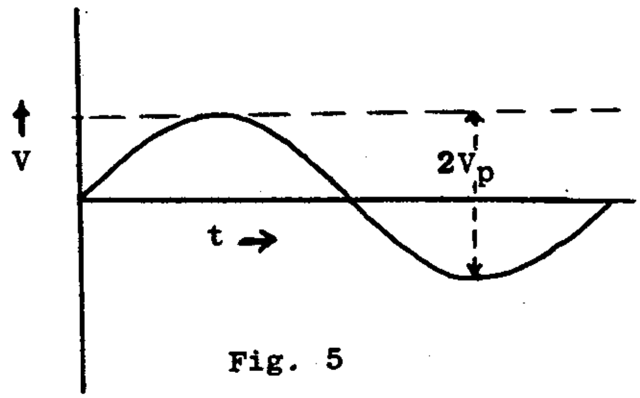


Fig. 5

$$\phi = (180)(\delta x/x) \text{ degrees.}$$

It should be noted that the inductor has a resistance (R'). This resistance must be included in Eqs. (6) and (8). Further, Eq. (9) will not hold exactly because of this fact.

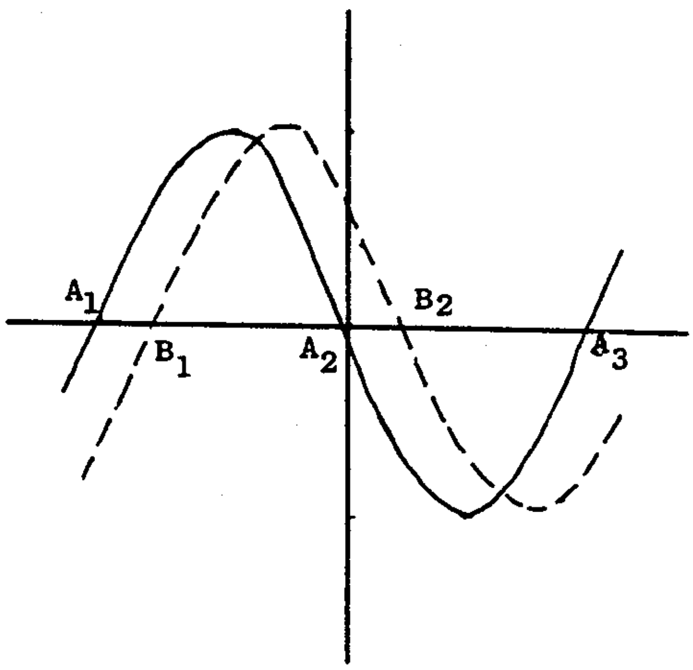
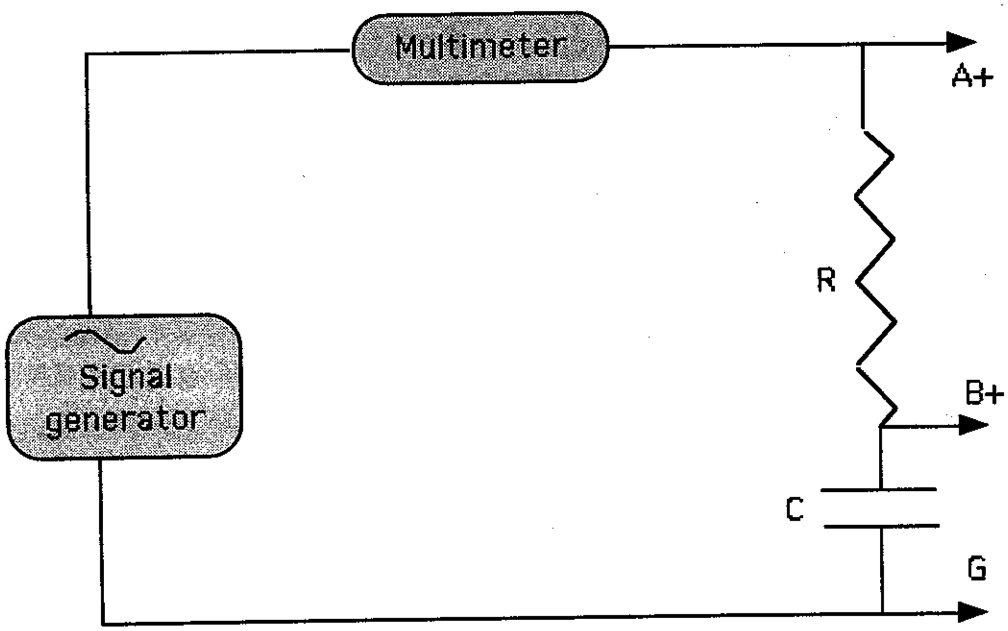


Fig. 6

Procedure:

Unit 1. AC circuit containing R and C:

(a) Make the circuit as shown in Fig. 9-7a. Do not connect the multimeter in the circuit. Switch on the signal generator. The sine wave from the signal generator provides the external AC voltage of suitable V_E and f.



Fig, 9.7a

(b) Select the value of f between 300 Hz and 600 Hz, and the value of C between 0.1 μF and 0.06 μF. Calculate X_C. Keep R equal to about $1.2(X_C)$.

(c) Record the values of f, C and R.

(d) Set the multimeter to read AC voltage. Measure the total voltage (V_E), the potential difference across C (V_C) and the potential difference across R (V_R).

(e) Set the multimeter to read AC current and insert it in the circuit as shown in Fig. 9-7a. Record the value of the current (I) in the circuit. Make sure that the current remains constant throughout the experiment.

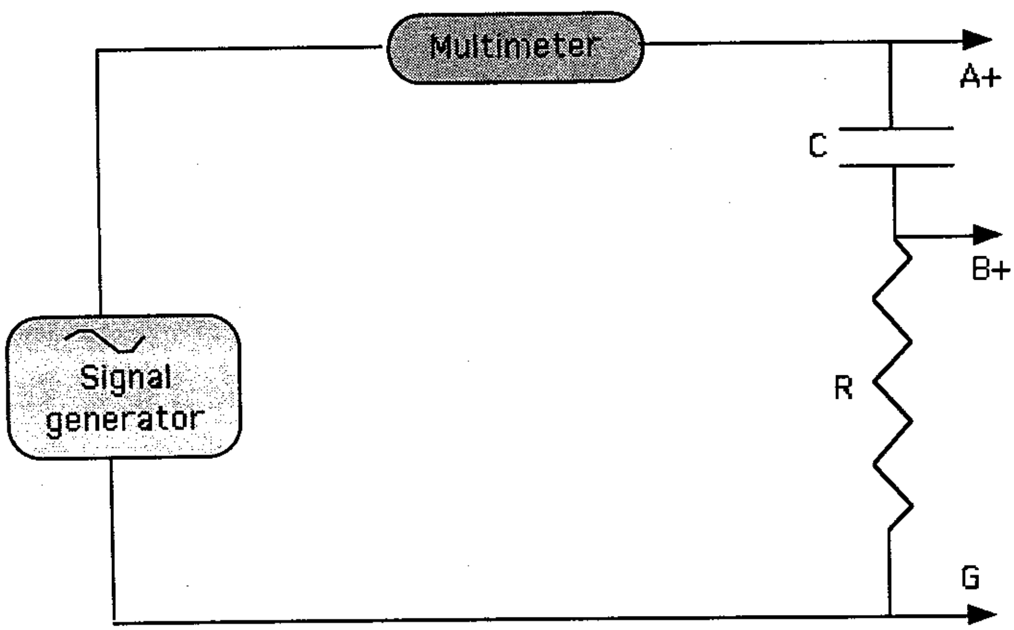
(f) Perform the initial turn-on procedure for the oscilloscope.

(g) Set trigger mode to AUTO, set vertical coupling of channels A and B to AC and SLOPE to +. Display mode can be CHOP or ALT.

h) Adjust the time/division, volt/division (channels A and B), and, horizontal and vertical positions to obtain the display as shown in Fig. 9-2.

(i) Make sure that the verniers (A and B) are in CAL position. Record volt/div (A and B) and time/div settings. Read the peak-to-peak voltages (in divisions) of A and B displays.

(j) Make the connections as shown in Fig. 9-7b. Adjust the volt/div (A and B) and time/div, if necessary.



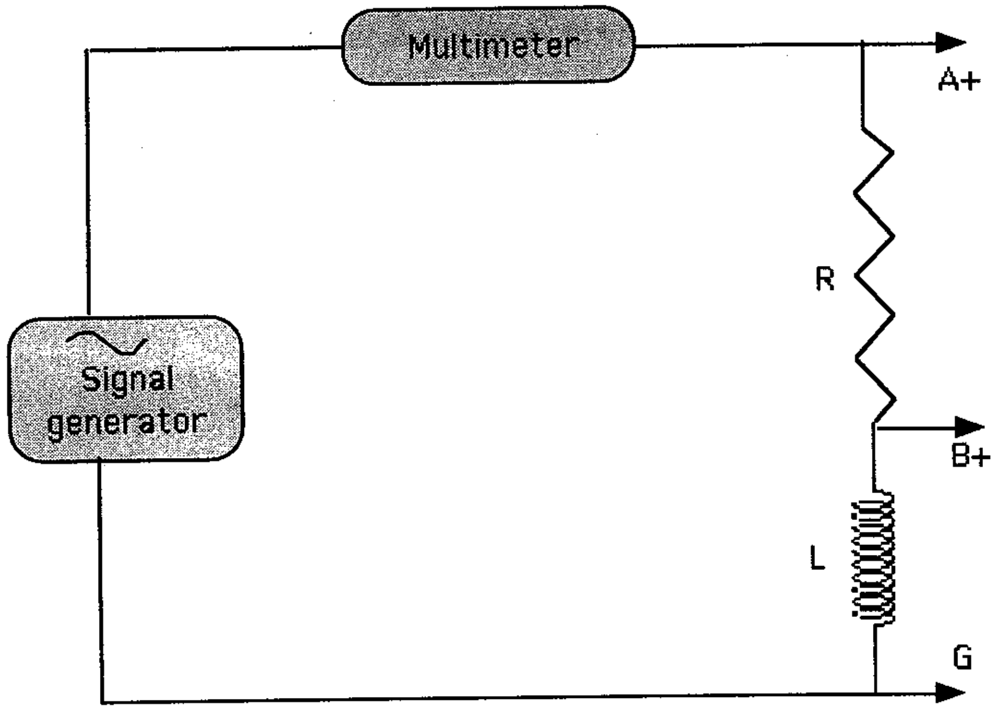
Fig, 9.7b

(k) Make sure that the curves are centered with respect to the horizontal axis. Read A_1B_1, A_2B_2, A_1A_2 and B_1B_2 (Fig. 9-6). Make a sketch of the display.

(l) If time permits, repeat the entire procedure by changing the values of f, C and R to obtain one more set of data.

Unit 2. AC circuit containing R and L:

(a) Make the circuit as shown in Fig. 9-8a. Do not connect the multimeter in the circuit. Switch on the signal generator. The sine wave from the signal generator provides the external AC voltage of suitable V_E and f.



Fig, 9.8a

(b) Select the value of f between 300 Hz and 600 Hz. Calculate X_L. Keep R equal to about 1.2(X_L).

(c) Record the values of f, L and R and R'.

(d) Set the multimeter to read AC voltage. Measure the total voltage (V_E), the potential difference across L (V_L) and the potential difference across R (V_R).

(e) Set the multimeter to read AC current and insert it in the circuit as shown in Fig. 9-8a. Record the value of the current (I) in the circuit. Make sure that the current remains constant throughout the experiment.

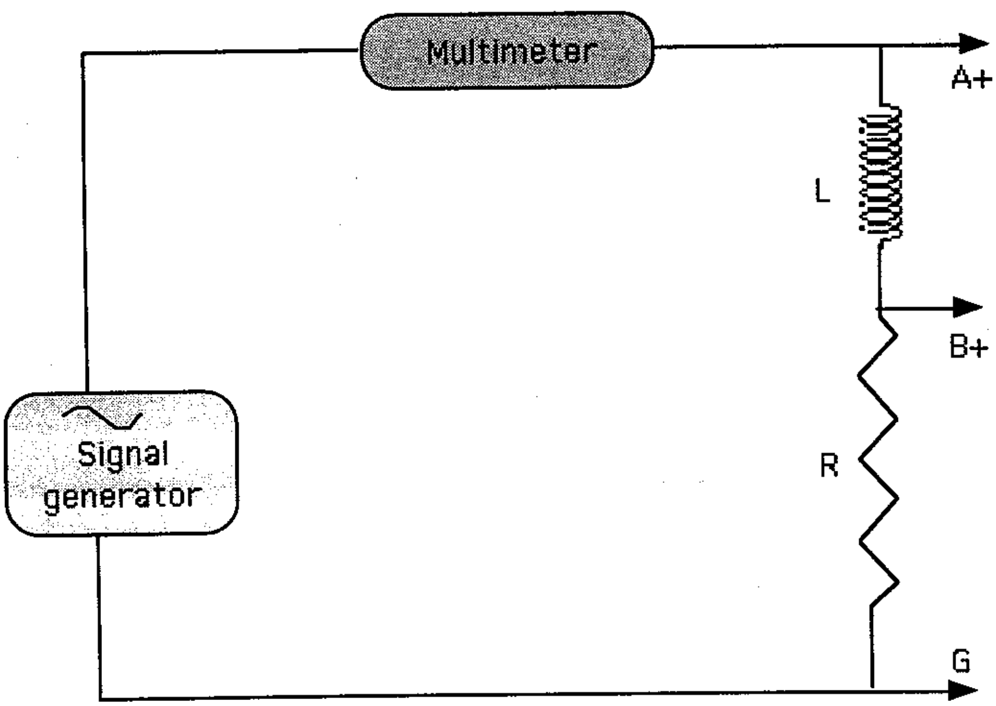
(f) Perform the initial turn-on procedure for the oscilloscope.

(g) Set trigger mode to AUTO, set vertical coupling of channels A and B to AC and SLOPE to +. Display mode can be CHOP or ALT.

(h) Adjust the time/division, volt/division (channels A and B), and, horizontal and vertical positions to obtain the display as shown in Fig. 9-4.

(i) Make sure that the verniers (A and B) are in CAL position. Record volt/div (A and B) and time/div settings. Read the peak-to-peak voltages (in divisions) of A and B displays.

(j) Make the connections as shown in Fig. 9-8b. Adjust the volt/div (A and B) and time/div, if necessary.



Fig, 9.8b

(k) Make sure that the curves are centered with respect to the horizontal axis. Read A_1B_1, A_2B_2, A_1A_2 and B_1B_2 (Fig. 9-6). Make a sketch of the display.

(l) If time permits, repeat the entire procedure by changing the values of f and R to obtain one more set of data.

York College of The City University of New York

Physics II

Name:

Experiment No. 9: Pre-Lab Questionnaire

1. In a circuit containing R and C, the current ________________ the voltage by an angle ϕ given by ____________________________

2. In a circuit containing R and L, the current ________________ the voltage by an angle ϕ given by ____________________________

3. In this experiment, the oscilloscope is used to measure __________ __________ values of ________________________________ and the multimeter is used to measure ____________________ values of ____

4. If f = 450 Hz and C = 0.07 μF, the value of R should be __________ ohm, approximately.

5. In this experiment, the phase difference between the applied voltage and current is determined by ______________________________ ____

6. Why do we have to change the circuit shown in Fig. 9-7a (or Fig. 9-8 a) to the circuit shown in Fig. 9-7b (or Fig. 9-8b) to determined the phase difference ϕ between the applied voltage and current?

Experiment No. 9

Name:

Marks:

Partner:

Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

DATA SHEET

Unit 1: AC Circuit Containing R and C:

Frequency f =

Resistance R =

Capacitance C =

Multimeter readings:

I =

V_E = ; V_C = ; V_R =

Oscilloscope readings:

Volt/div (A) = ; Volt/div (B) = ; Time/div =

V_A (peak-to-peak A) = ; V_B (peak-to-peak B) =

A_1B_1 = ; A_2B_2 = ; A_1A_2 = ; B_1B_2 =

Sketch of the display (label the curves voltage and current):

Unit 2: AC Circuit Containing R and L:

Frequency f =

Resistance R =

Resistance of inductor R' =

Inductance L =

Multimeter readings:

I = ;

V_E = ; V_L = ; V_R =

Oscilloscope readings:

Volt/div (A) = ; Volt/div (B) = ; Time/div =

V_A (peak-to-peak A) = ; V_B (peak-to-peak B) =

A_1B_1 = ; A_2B_2 = ; A_1A_2 = ; B_1B_2 =

Sketch of the display (label the curves voltage and current):

Calculations:

Unit 1:

Set No. ____

$$X_C(\text{theoretical}) = \frac{1}{2\pi fC} =$$

$$Z(\text{theoretical}) = \sqrt{R^2 + X_C^2} =$$

$$\phi(\text{theoretical}) = \tan^{-1}\left(\frac{X_C}{R}\right) =$$

$$V_T = \sqrt{V_R^2 + V_C^2} =$$

From peak-to-peak readings:

$$V_E' =$$

$$V_C' =$$

$$X_C'(\text{experimental}) = \frac{V_C}{I} =$$

$$Z'(\text{experimental}) = \frac{V_E}{I} =$$

$\delta x = \frac{1}{2}(A_1B_1+A_2B_2) =$

$x = \frac{1}{2}(A_1A_2+B_1B_2) =$

$\phi(\text{expererimental}) = 180\,\frac{\delta x}{x} =$

Percent difference between					
V_T & V_E	V'_E & V_E	V'_C & V_C	X'_C & X_C	Z' & Z	ϕ' & ϕ

Unit 2:

Set No, _____

X_L(theoretical) = $2\pi f L$ =

Z(theoretical) = $\sqrt{R^2 + X_L^2}$ =

ϕ(theoretical) = $\tan^{-1}\left(\frac{X_L}{R}\right)$ =

$V_T = \sqrt{V_R^2 + V_L^2}$ =

From peak-to-peak readings:

V_E' =

V_L' =

X_L'(experimental) = $\frac{V_L}{I}$ =

Z' (experimental) = $\frac{V_E}{I}$ =

$\delta x = \frac{1}{2}(A_1B_1+A_2B_2) =$

$x = \frac{1}{2}(A_1A_2+B_1B_2) =$

ϕ(expererimental) $= 180\,\frac{\delta x}{x} =$

Percent difference between					
V_T & V_E	V'_E & V_E	V'_L & V_L	X'_L & X_L	Z' & Z	ϕ' & ϕ

Questions:

1. What happens when an AC voltage is applied to an inductor? Explain briefly.

2. Why is it necessary to have the vertical verniers in calibrated position? What about the horizontal verniers?

3. Does the phase difference decrease or increase as f increases in Unit 1? In Unit 2? Explain briefly.

4. What is the difference between the relative positions of displays A and B for Units 1 and 2? Why do the relative positions of A and B displays for Units 1 and 2 differ?.

Experiment No. 10
ALTERNATING CURRENT CIRCUITS II

Objective: To study the AC circuit containing a resistor, a capacitor and an inductor.

Apparatus: A cathode ray oscilloscope, a decade resistance box, a capacitor, an inductor, a multimeter, a signal generator.

Theory: Let an external alternating voltage of effective value V_E and of frequency f be applied to a circuit containing R, L and C as shown in Fig. 1.

The effective current I in the circuit is given by

$$I = V_E/Z, \qquad (1)$$

the impedance Z, in this case, being

$$Z = \sqrt{R^2 + (X_L - X_C)^2}, \qquad (2)$$

where the inductive reactance

$$X_L = 2\pi fL, \qquad (3)$$

and the capacitive reactance

$$X_C = 1/2\pi fC. \qquad (4)$$

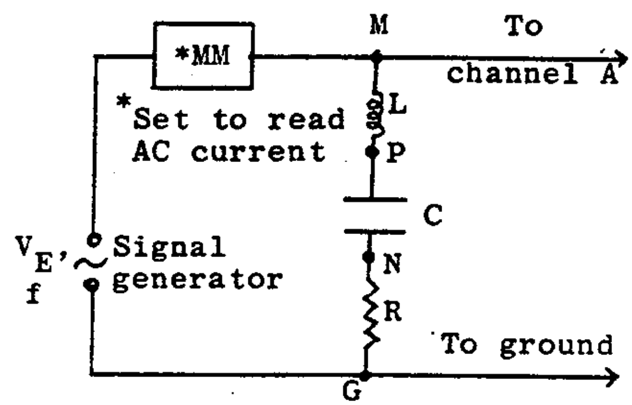


Fig. 1

If Eq. (2) is multiplied by I, we get

$$V_E = \sqrt{V_R^2 + (V_L - V_C)^2}\ . \qquad (5)$$

In this case, the voltage leads the current by an angle given by

$$\tan\phi = \frac{X_L - X_C}{R}\ . \qquad (6)$$

If $X_L - X_C = 0$, the circuit is purely resistive or a resonant circuit. The natural frequency f_r of a circuit having an inducatance L and a capacitance C, is given by

$$f_r = 1/2\pi\sqrt{LC}. \qquad (7)$$

Obviously, resonance occurs if the frequency of the external AC voltage is equal to the natural frequency f_r of the circuit. At resonance frequency, the impedance of an R-L-C circuit is minumum (=R) and hence the current in the circuit is maximum. Further, Eq. (6) indicates that $\phi = 0$ for a resonant circuit. In other words, AA' and BB' (shown in Fig. 22-6, given on page 9-3P) will be zero at resonance. Also see Fig. 3 of this experiment.

The signals applied to channels A and B constitute 2 sine waves of the same frequency but of different amplitudes. Thus if we set the DISPLAY switch at A vs. B, signal 'A' will be applied to the vertical deflection plates and signal 'B' will be applied to the horizontal deflection plates. Thus two mutually perpendicular simple harmonic motions will be impressed upon the electron beam which will trace an ellipse on the screen (as shown in Fig. 2). This is a Lissajous figure. More complicated Lissajous figures are obtained when the ratio of the frequencies is 2:1, 3:1, 2:3, etc. In this case, however, at resonance, when the phase difference between the two signals is zero, the ellipse is reduced to a straight line.

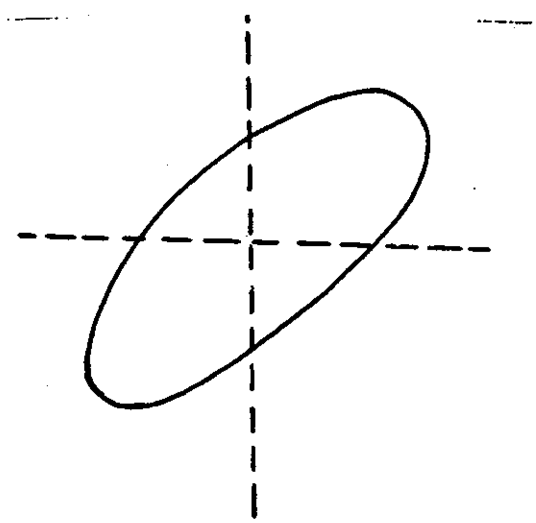


Fig. 2

In this experiment, resonance is studied by (a) obtaining the maximum current (I_{max}), (b) observing zero phase difference between V_A and V_B(the signals applied to the channels A and B), and (c) setting the DISPLAY to A vs. B and reducing the ellipse to a straight line.

Voltages and phase difference are measured by means of the oscilloscope as explained on pages 9-2P and 9-3P.

Procedure:

Unit 1. Measurement of Z and the phase difference:

(a) Make the circuit as shown in Fig. 10.3a. Do not connect the multimeter in the circuit. Switch on the signal generator. The sine wave from the signal generator provides the external AC voltage of suitable V_E and f.

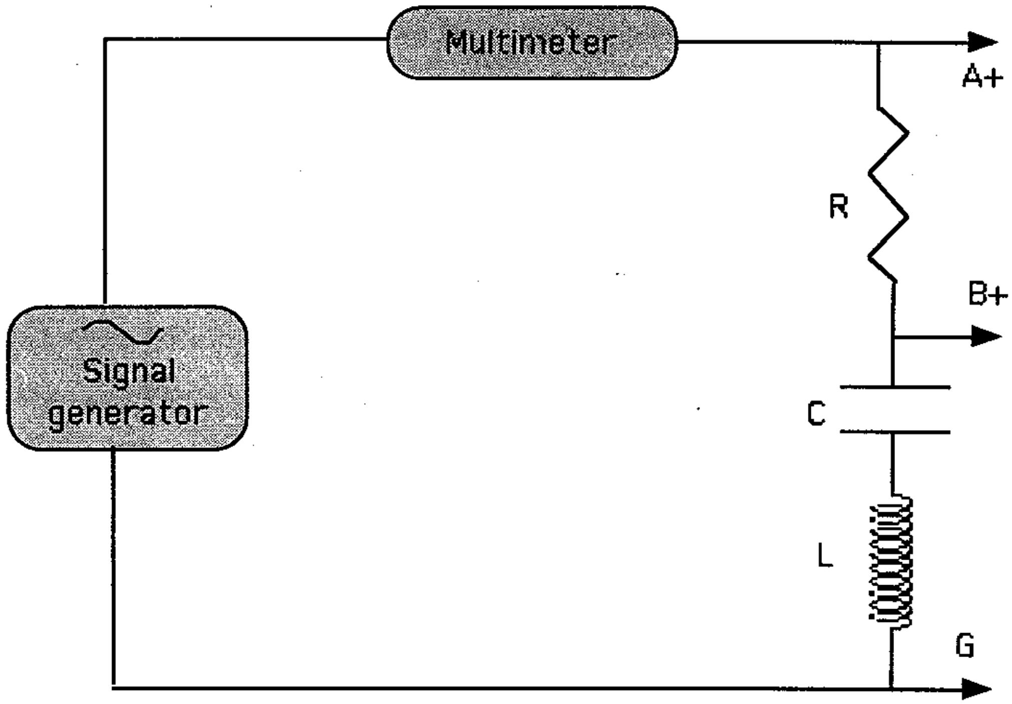


Fig. 10.3a

(b) Select the value of f between 300 Hz and 600 Hz, and the value of C between 0.1 μF and 0.06 μF. Calculate $X = |X_L - X_C|$. Keep R equal to about 1.2(X).

(c) Record the values of f, L, C, R and R'.

(d) Set the multimeter to read AC voltage. Measure the total voltage (V_E), the potential difference across R (V_R), the potential difference across L (V_L), the potential difference across C (V_C), the potential difference across L and C (V_{LC}).

(e) Set the multimeter to read AC current and insert it in the circuit as shown in Fig. 10.3a. Record the value of the current (I) in the circuit. Make sure that the current remains constant throughout the experiment.

(f) Switch on the oscilloscope.

(g) Set trigger mode to AUTO, set vertical coupling of channels A and B to AC and SLOPE to +. Display mode can be CHOP or ALT.

(h) Adjust the time/division, volt/division (channels A and B), and, horizontal and vertical positions to obtain the display as shown in Fig. 9.2.

(i) Make sure that the VAR controls (A and B) are in CAL position. Record volt/div (A and B) and time/div settings. Read the peak-to-peak voltages (in divisions) of A and B displays.

(j) Make the connections as shown in Fig. 10.3b. Adjust the volt/div (A and B) and time/div, if necessary.

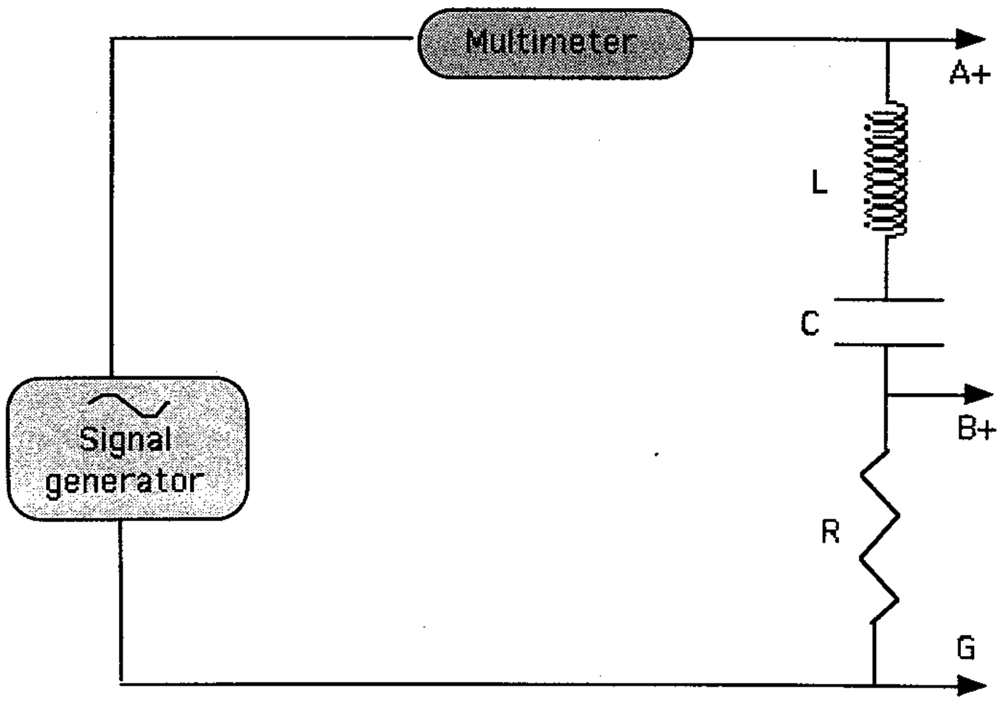


Fig. 10.3b

(k) Make sure that the curves are centered with respect to the horizontal axis. Read A_1B_1, A_2B_2, A_1A_2 and B_1B_2 (Fig. 9-6). Make a sketch of the display.

(l) If time permits, repeat the entire procedure by changing the values of f, C and R to obtain one more set of data.

Unit 2. Study of resonance:

(a) Calculate the natural frequency f_r of the circuit by using Eq. (7). Set the frequency of the signal generator near f_r.

(b) Vary the frequency of the signal generator such that the current in the circuit (as indicated by the multimeter) is maximum. Record this frequency (f_1) and current I'_{max}.

(c) Eliminate the multimeter from the circuit, set it to read AC voltage and measure V_E.

(d) Adjust the centering of A and B displays with respect to the horizontal axis, as accurately as possible. Adjust the frequency of the signal generator until there is no phase difference between the A and B displays (as shown in Fig. 9-4). Record the frequency of the signal generator (f_2).

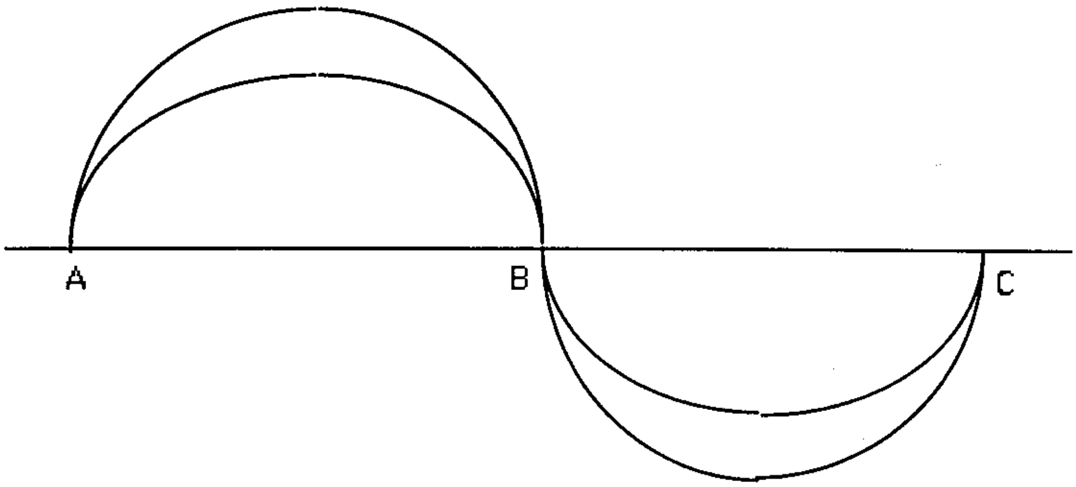


Fig. 10.4

(e) Change the display to A vs. B by selecting X-DEFL for trigger source (key [19]). In general, an ellipse will be displayed on the screen. Adjust the frequency of the signal generator until the ellipse is reduced to a straight line. Record the frequency of the signal generator (f_3).

(f) If time permits, repeat the entire procedure by changing C and/or R.

Note that volt/div (A and B) and time/div, and, vertical and horizontal VAR controls may have to be adjusted in steps (d) and (e).

Further, if the signals are weak, the displays may be distorted or other difficulties may be encountered in steps (d) and (e). In such a case, either skip these steps, or change R and C, and, start from step (a) of the procedure.

York College of The City University of New York

Physics II Name:

Experiment No. 10: Pre-Lab Questionnaire

1. If $X_L = X_C$, what kind of circuit do we have?

2. If L 1.5 henry and C 0.06 μF, the natural frequency of the circuit is

____

3. Describe the methods of determining resonance frequency in this experiment.

4. In the first part of this experiment, the ________________ controls should be in calibrated position. Explain your answer.

5. Why the time/division control need not be in calibrated position while determining the phase difference between the applied voltage and current?

Experiment No. 10

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

DATA SHEET

Unit 1: AC Circuit Containing RLC:

Frequency f =

Resistance R =

Resistance of inductor R' =

Capacitance C =

Inductance L =

Multimeter readings:

I = ; V_E = ; V_R =

V_{LC} = ; V_L = ; V_C =

Oscilloscope readings:

Volt/div (A) = ; Volt/div (B) = ; Time/div =

V_A (peak-to-peak A) = ; V_B (peak-to-peak B) =

A_1B_1 = ; A_2B_2 = ; A_1A_2 = ; B_1B_2 =

Sketch of the display (label the curves voltage and current):

Unit 2: Resonance:

R = ; R' = ; C = ; L =

f_T (theoretical) =

I'_{max} (experimental) = ; V_E =

f_1 = ; f_2 = ; f_3 =

Make similar data sheets for each set.

Calculations:

Unit 1:

Set No. ____

$$X_C(\text{theoretical}) = \frac{1}{2\pi f C} =$$

$$X_L(\text{theoretical}) = 2\pi f L =$$

$$X_{LC} = | X_L - X_C |$$

$$Z(\text{theoretical}) = \sqrt{(R+R')^2 + (X_L - X_C)^2} =$$

$$\phi(\text{theoretical}) = \tan^{-1}\left(\frac{X_L - X_c}{R + R'}\right) =$$

$$V_X = | V_L - V_C | =$$

$$V_T = \sqrt{V_R^2 + V_{LC}^2} =$$

From peak-to-peak readings:

$$V_E' =$$

$$V_{LC}' =$$

$$X_{LC}'(\text{experimental}) = \frac{V_{LC}}{I} =$$

$$Z'(\text{experimental}) = \frac{V_E}{I} =$$

$\delta x = \frac{1}{2}(A_1B_1+A_2B_2) =$

$x = \frac{1}{2}(A_1A_2+B_1B_2) =$

ϕ (expererimental) $= 180\frac{\delta x}{x} =$

Percent difference between						
V_X & V_{LC}	V_T & V_E	V_E' & V_E	V_{LC}' & V_{LC}	X_{LC}' & X_{LC}	Z' & Z	ϕ' & ϕ

Unit 2:

Set No, _____

I_{max} (theoretical) $= V_E/(R + R') =$

Percent difference between			
I'_{max} & I_{max}	f_r & f_1	f_r & f_2	f_r & f_3

Questions:

1. Why is it not necessary for the horizontal vernier to be in calibrated position in this experiment?

2. How will you measure V_L, V_R and V_C in Unit 1 of this experiment by using the oscilloscope?

3. What is the main source of error in Unit 1 of this experiment?

4. Can the current ever lead the voltage in Unit 1? Explain.

5. What will happen if in Unit 2, the resistance R is changed after the frequency has been adjusted to obtain I_{max}?

Experiment No. 12
Characteristics Of A Triode

Objective:

(a) To study the characteristics of a triode.
(b) To study a simple amplifier circuit.

Apparatus:

A triode mounted on a test board, power supply, a signal generator, two multimeters, a load resistor, a cathode ray oscilloscope.

Theory:

A triode, shown schematically in Fig. 1, is a vacuum tube consisting of 3 electrodes, a cathode C, a grid G and a plate P, sealed in an evacuated envelope. The cathode C is heated by the filament F to give off electrons. The electrons are accelerated towards the plate P which is kept at a high positive potential with respect to the cathode. The grid G is a mesh of wire and it is closer to the cathode than the plate. Thus the voltage on the grid controls the flow of electrons from the cathode to the plate quite effectively.

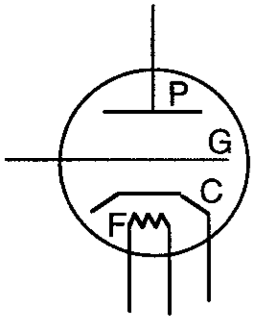


Fig. 1

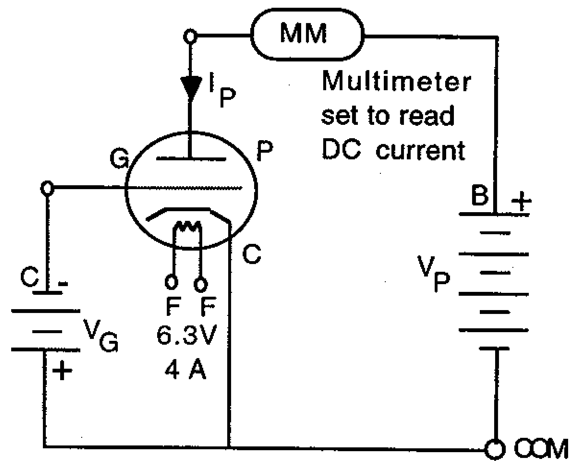


Fig. 2

Consider the triode circuit shown in Fig. 2. By keeping the grid voltage V_G constant, the plate current I_P van be measured for different values of V_P. Then a graph of I_P vs. V_P can be plotted. Three such graphs for 3 different grid voltages are shown in Fig. 3. These curves are known as the plate characteristic curves of the triode. Another type of characteristic curves of a triode are the mutual characteristic curves which are graphs of I_P vs. V_G at constant values of V_P.

Now consider the point A (Fig. 3) for which the plate current, plate voltage and grid voltage are I_{P2}, V_{P1} and V_{G1}, respectively. If the grid voltage is reduced by $(V_{G1} - V_{G2}) = 2$ volt, the plate current is reduced to I_{P2}. By increasing the plate voltage from V_{P1} to V_{P2}, the plate current will be restored to the value I_{P1}. The amplification factor, μ, of a triode at a constant plate current is defined as

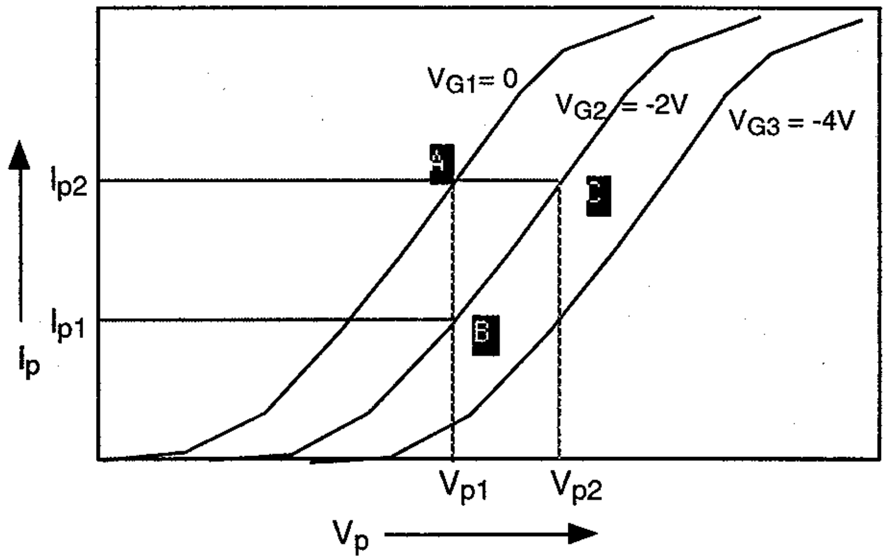


Fig. 3. Plate Characteristics Of A Triode

$$\mu = \left(\frac{V_{P2} - V_{P1}}{V_{G1} - V_{G2}}\right)_i \qquad (1)$$

Another parameter of interest is the triode plate resistance R_P which is defined by

$$R_p = \frac{\Delta V_P}{\Delta I_P} \qquad (2)$$

Here ΔV_P is a small change in V_P,
ΔI_P is a small change in I_P,
and V_G is kept constant.

Thus if ΔV_P $(= V_{P2} - V_{P1})$ and ΔI_P $(= I_{P2} - I_{P1})$ are small (see Fig. 3),

$$R_p = \frac{V_{P2} - V_{P1}}{I_{P2} - I_{P1}} \qquad (3)$$

at the grid voltage V_{G2}.

A simple amplifier circuit is shown in Fig. 4. The sine wave signal V_I from the signal generator is connected in the grid circuit. This signal is displayed on channel A of the cathode ray oscilloscope. A load resistor R_L is connected in the plate circuit and the amplified output signal obtained across R_L is displayed on channel B. The grid bias and plate voltage are suitably adjusted to achieve amplification. If *m* is the amplification factor of the triode, then the input signal V_I will be amplified to mV_I. The the voltage across the total resistance (R_L + R_P) will be mV_I, of which only the fraction

$$\frac{R_L}{R_L + R_P}$$

is obtained across load resistor R_L.

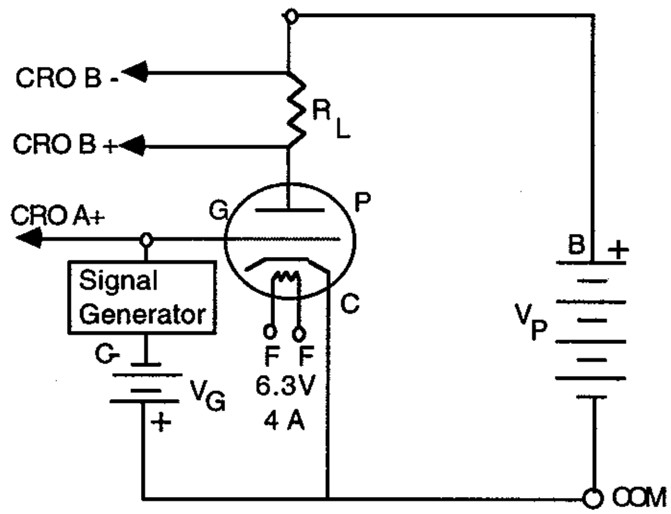


Fig. 4. A Simple Amplifier

Hence the signal V_A, across R_L, is given by

$$V_A = \frac{\mu V_I R_L}{R_L + R_P} \qquad (4)$$

The amplifier gain is defined as

$$\text{gain} = \frac{\mu R_L}{R_L + R_P} \qquad (5)$$

Procedure:

Unit 1: Characteristics Of A Triode:

(a) Make the circuit as shown in Fig. 2. Connect the filament FF to its power supply (6.3V, 4A). Connect the plate to B+ of the power supply and the terminal marked com to the cathode. Connect the grid to C-. Do not include the load resistor in the circuit. Include one multimeter in the circuit to measure the plate current as shown in the figure. The second multimeter will be used to measure DC voltages as described below.

(b) Adjust the second multimeter to read DC volts, connect it to C- and com and adjust the grid bias to -4 volt.

(c) Now connect the second multimeter between B+ and com and adjust the plate voltage to some multiple of 10 such that the plate current (read by the first multimeter) is nearly zero. Record the plate voltage and plate current.

(d) Increase the plate voltage in equal steps (of 10 or 15 volt) and record the plate voltage and plate current each time. Thus measure I_P for about 12 values of V_P.

(e) Repeat the procedure by keeping V_G = -2 volt and 0 volt.

(f) Plot the plate characteristics of the triode (similar to the curves shown in Fig. 3).

Unit 2: Amplifier Circuit:

(f) Measure the load resistance R_L by using the multimeter. Set up the circuit as shown in Fig. 4. Adjust the amplitude of the sine wave of the signal generator to about 2 volt and frequency to about 5000 Hz.

(g) Switch on the oscilloscope. Set MODE to NORM, the vertical coupling (A and B) to AC. The vertical verniers should be in calibrated position. The DISPLAY can be ALT or CHOP. Set the trigger mode to AUTO (it can be changed if necessary) and adjust the trigger level if necessary. Switch on the signal generator. Set the grid bias and plate voltage corresponding to the linear segment (middle portion) of the plate characteristics. Adjust the volt/div (channels A and B) to obtain proper displays on both channels.

(h) Record the data for Unit 2 on the data sheet.

(i) Change V_I, V_P, V_G, etc. slightly to obtain more sets of data.

Note: To achieve $V_g = 0$, connect V_g and the grounded cathode with a black wire.

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Physics II Name:

Experiment No. 12: Pre-Lab Questionnaire

1. What are plate characteristics of a triode?

2. Describe the function of the grid.

3. What is a convenient way to make V_g zero?

4. In Fig. 4, which shows a simple amplifier circuit, CRO channel A displays ______________________________ and CRO channel B displays ______________________________

Experiment No. 12

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

DATA SHEET

Observations:

Unit 1: Plate Characteristic Curves:

No.	Plate voltage (V_p)	Plate Current (I_p)		
		$V_g = -4$ V	$V_g = -2$ V	$V_g = 0$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Unit 2: Amplifier Circuit:

Load resistance R_L =

Plate voltage = Grid bias =

Volt/Div (A) = Volt/Div (B) =

Peak-to-peak Height (A) = divisions

Peak-to-peak Height (B) = divisions

Effective value of input signal (by multimeter) =

Effective value of amplified signal (by multimeter) =

Calculations:

Unit 1:

Plot the plate characteristics.

Use the middle portions of the curves to fill out the following.

Calculation of μ:

Curve numbers	V_{Gi}	V_{Gj}	V_{pi}	V_{pj}	μ
i=1 & j=2					
i=2 & j=3					
i=1 & j=3					

Calculation of plate resistance, R_p:

Curve number	V_G	I_{pi}	I_{pj}	V_{pi}	V_{pj}	R_p
1						
2						
3						

Unit 2:

From the above table,

μ =

R_p =

R_L =

Theoretical value of gain [Eq. (5)]=

Gain (from oscilloscope readings) =

Gain (from multimeter readings) =

Questions:

1. Define the terms amplification factor, plate resistance and gain.

2. Briefly explain the working of an amplifier circuit.

3. How would you choose the operating voltages (V_p and V_g) for the triode to function as an amplifier? What would happen if the operating voltages in Unit 2 correspond to the beginning of the plate characteristics?

4. In Unit 2, was the output signal distorted? If yes, why?

Experiment No. 13
Lenses

Objective:

(a) To determine the focal length of a convex lens by plane mirror method.

(b) To determine the focal length of a convex lens and the focal length of a concave lens by conjugate foci method.

Apparatus:

An optical bench, 2 convex lenses, a concave lens, a plane mirror, object and image pins, light source and ground glass screen.

Theory:

A lens (Figs. 13-1 and 13-2) consists of a refracting medium bounded by two spherical surfaces. A lens has two principal foci (F_1 and F_2). The line passing through F_1 and F_2 is known as the principal axis of the lens. Point O is called the optical center of the lens. The following rules define the optical center O, and, the two principal foci F_1 and F_2:

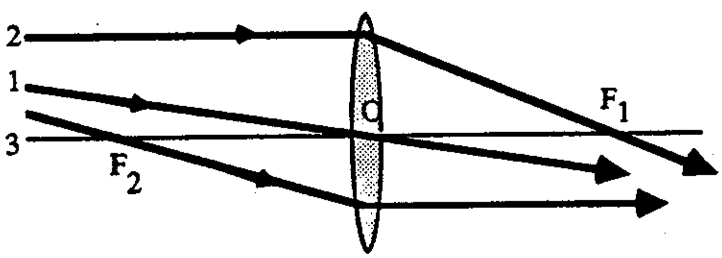

Fig. 13-1

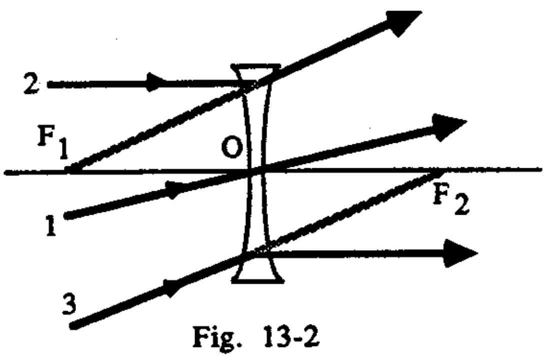

Fig. 13-2

(1) An incident ray of light passing through the optical center is not deviated. (See rays marked 1 in the above figures.)

(2) If an incident ray is parallel to the principal axis (rays marked 2 in the above figures), then the refracted ray passes through the first principal focus F_1 (as in Fig. 13-1) or appears to come from the first principal focus F_1 (as in Fig. 13-2).

(3) If an incident ray passes through the second principal focus F_2 (as in Fig. 13-1) or is directed towards the second principal focus F_2 (as in Fig. 13-2), the refracted is parallel to the principal axis. (See rays marked 3 in Figs. 13-1 and 13-2.)

The above rules are used to draw ray diagrams and to locate the positions of images as shown in Figs. 13-3 and 13-4.

Focal length: The distance of the first principal focus from the optical center (which is also numerically equal to the distance of the second principal focus from the optical center) is defined as the focal length (f) of the lens. The focal length f is positive for a convex (converging) lens and it is negative for a concave (diverging) lens.

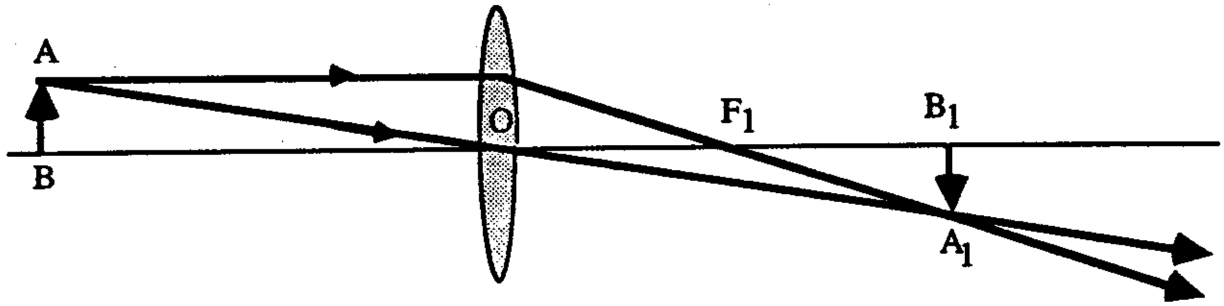

Fig. 13-3

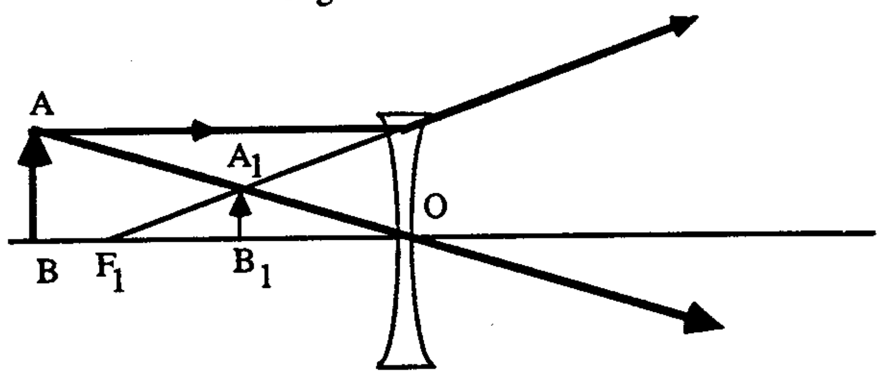

Fig. 13-4

In Fig. 13-3, the rays starting from the point A (of the object AB) pass through the point A_1 after refraction through the lens. Thus the image A_1 which is formed by the actual intersection of the refracted rays, is the real image of the point A. Similarly, B_1 is the real image of point B.

In Fig. 13-4, the rays starting from the point A (of the object AB) appear to come from the point A_1 after refraction through the lens. Thus the image A_1 which is not formed by the actual intersection of the refracted rays, is the virtual image of the point A. Similarly, B_1 is the virtual image of point B.
The path of a ray is reversible. Thus if a real object is placed at B_1 (Fig. 13-3) a real image is obtained at B. Thus B and B_1 are known as conjugate foci. Similarly, if in Fig. 13-4, a virtual object is placed at B_1, a real image will be formed at B. Thus B and B_1 are conjugate foci.

The distance BO is known as the object distance (p) and the distance O B_1 is known as the image distance (q).

Convention of signs:

The distances which are actually traversed by the rays are taken to be positive and those which are not actually traversed by the rays are taken to be negative. Thus the focal length of a convex lens (in Fig. 13-1) and the object distances in Figs. 13-3 and 13-4 which are actually traversed by light rays are positive. The image distance (q) in Fig. 13-3 is also positive because the rays actually travel from the lens to the image A_1B_1. The focal length of the concave lens (Fig. 13-2) is negative and the image distance (q) in Fig. 13-4 is negative because the rays appear to come from the virtual image A_1B_1.

The relationship between the object distance (p), the image distance (q) and the focal length (f) is

$$1/p + 1/q = 1/f. \qquad (1)$$

This formula is used to find the focal length (f) by the conjugate foci method.

The magnification (m) is defined by

$$m = (\text{size of image})/(\text{size of object}) = -q/p. \qquad (2)$$

If two lenses of focal lengths f_1 and f_2 are placed in contact, the focal length of the combination (f) is given by

$$1/f = 1/f_1 + 1/f_2. \qquad (3)$$

Plane mirror method of determining the focal length of a convex lens:

This method is especially suitable for determining the focal length of a convex lens of large focal length. If an object AB (Fig. 13-5) is placed in the focal plane of the convex lens such that the point A is at the principal focus, then all the rays starting from A will become parallel to the principal focus after refraction through the convex lens.

This beam of parallel rays is incident normally on the plane mirror M and thus it is reflected back along its own path. The reflected beam is parallel to the principal axis of the lens and thus it is brought to a focus at the principal focus of the lens (point A). Thus the image of AB is formed at A'B' such that the point A' of the image coincides with the point A of the object.

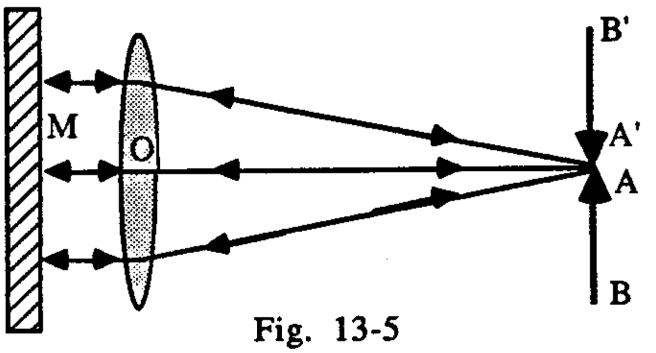

Fig. 13-5

The method of no parallax is adopted to locate the position of images. Parallax is the relative motion observed between two objects (or between an object and an image) which are not situated at the same point, due to the motion of the observer. For example, consider the image A_1 (Fig. 13-6). If the image pin is placed at A_2' (or A_3'), points A_1 and A_2' (or A_1 and A_3') will appear to move relative to each other when the observer moves sideways. Thus parallax will be observed between A_1 and A_2' (and, A_1 and A_3'). However, if the tip of the image pin is at A_1' (coinciding with A_1), there no parallax will be observed between A_1 and A_1'.

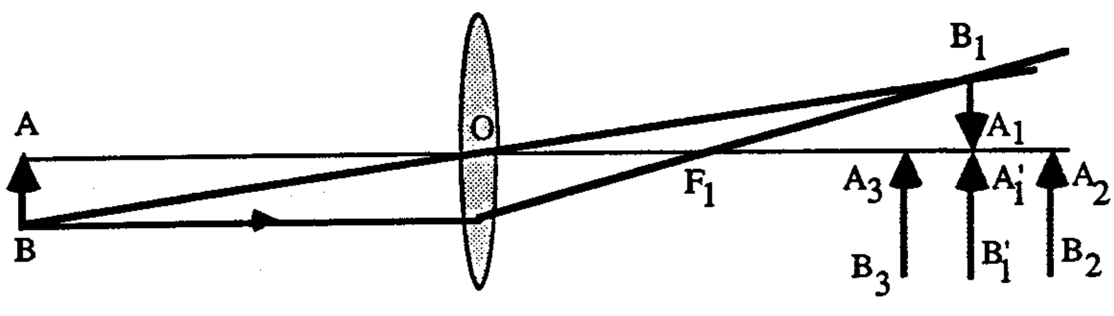

Fig. 13-6

Conjugate foci method of determining the focal length of a convex lens:

In Fig. 13-6, AB is an object whose image is A_1B_1. Thus points A and A_1 are the conjugate foci. Further, in Fig. 13-6, the image A_1B_1 is real. Thus the method of no parallax can be employed for determining the object distance (p) and the image distance (q). Then the focal length f can be calculated from Eq. (1). Alternatively, a well-defined image of a source of light (placed at AB) can be obtained on a ground glass screen (placed at $A_1'B_1'$). Thus the object and image distances can be measured.

Conjugate foci method of determining the focal length of a concave lens:

The image of a real object in a concave (diverging) lens is always virtual. Thus its focal length can not be determined by the methods adopted for determining the focal length of convex lenses described above. However, the image of a virtual object formed by a concave lens is real. Therefore, the focal length of a concave lens can be determined by the method described below (Fig. 13-7)

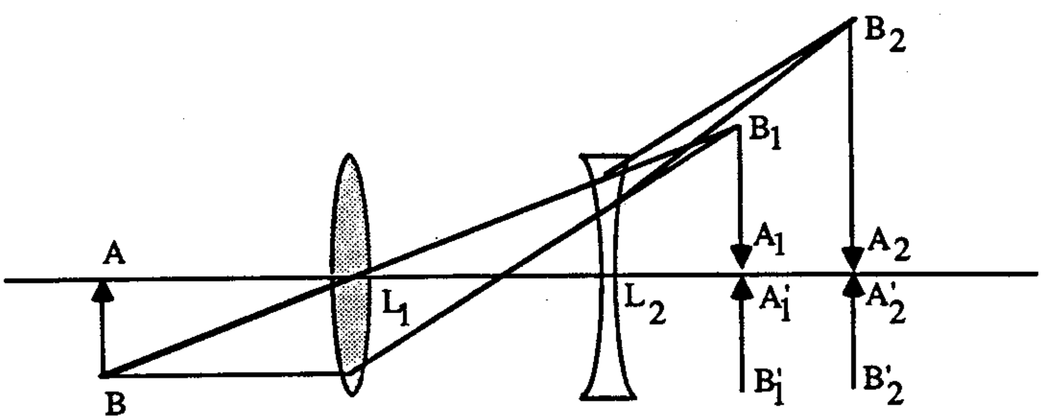

Fig. 13-7

The real image of the object AB is formed by the convex lens L_1 at A_1B_1. This image is located by the image pin $A_1'B_1'$. Alternatively, a light source can be placed at AB and its real image can be obtained by placing a screen at A_1. Now let a concave lens L_2 be placed between the convex lens L_1 and the image A_1B_1. In such a case, the real image A_1B_1 (of the object AB formed by the convex lens L_1) serves as a virtual object for refraction through the concave lens L_2. This is because the rays refracted by lens L_1 pass through lens L_2 before they actually meet at the real image A_1B_1. The concave lens forms a real image A_2B_2 of the virtual object A_1B_1. This real image can be located by the method of no parallax by using the image pin $A_2'B_2'$ or the image can be located by using a light source (placed at AB) and a screen (placed at A_2B_2). Obviously, for the concave lens L_2, the object distance (p) is the distance from O_2 to A_1, and the image distance (q) is the distance from O_2 to A_2. Thus the focal length of the concave lens can be calculated from Eq. (1).

There is another way of looking at the situation depicted in Fig. 13-7. Let an object pin be placed at $A_2'B_2'$. The concave lens L_2 produces a virtual image $A_1'B_1'$ of this object $A_2'B_2'$. This virtual image serves as a real object for refraction through the convex lens L_1 and thus a real image is formed by the convex lens at A'B'.

Procedure:

Unit 1. Determination of the focal length of a convex lens by plane mirror method:

(a) Mount the plane mirror, a convex lens and a pin on the optical bench as shown in Fig. 13-5. Rotate the plane of the mirror so as to have the tip of the pin, the tip of the image and the optical center of the lens in a straight line.

(b) Adjust the position of the pin along the optical bench and remove the parallax between the tip of the pin and the tip of the image.

(c) Record the position of the lens and the position of the pin.

(d) Repeat steps (a), (b) and (c) twice.

Units 2 & 3. Determination of the focal length of a convex lens and the focal length of a concave lens by the conjugate foci method:

(e) Mount the light source S (Fig. 13-8) near one end of the optical bench. Mount the convex lens L_1 such that the object distance SL_1 lies between f_1 and $2f_1$, where f_1 is the approximate focal length of the convex lens. Mount the screen G_1 as shown in Fig. 13-8. Adjust the position of the screen (and of the lens, if necessary) to obtain a sharp image of the light source on the screen.

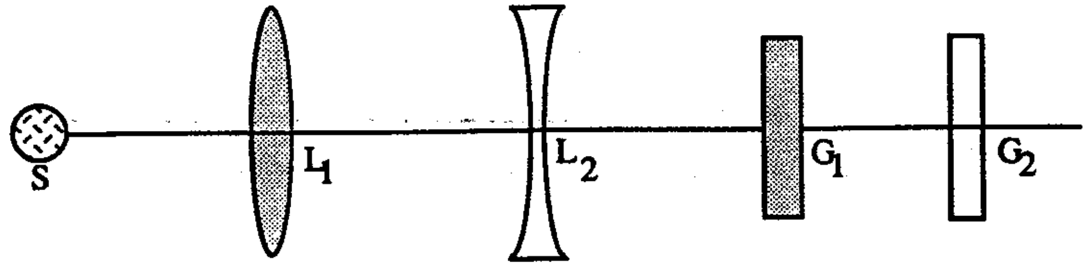

Fig. 13-8

(f) Record the positions of the lens L_1, of the light source S and of the screen G_1. The distance between S and L_1 is the object distance (p_1) and the distance between L_1 and G_1 is the image distance (q_1) for the convex lens.

(g) Keep the positions of the source and convex lens L_1 fixed in the following steps.

(h) Now mount the concave lens L_2 between the convex lens L_1 and the screen G_1. Move the screen to position G_2 so as to obtain a sharp image of the light source S on the screen. Thus the image of the light source is formed at G_2 by the two lenses L_1 and L_2.

(i) Note that for the concave lens L_2, the image formed by the convex lens L_1 is the virtual object whose image is formed by the concave lens L_2 at the new position of the screen G_2. Thus for the concave lens, the distance between L_2 and G_1 is the object distance (p_2) and the distance between L_2 and G_2 is the image distance (q_2).

(j) Record the positions of L_2 and G_2.

(k) Change the object distance for the convex lens by about 1.5 cm and repeat steps (e) through (j) twice.

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Physics II Name:

Experiment No. 13: Pre-Lab Questionnaire

1. In a converging lens, if an incident ray is parallel to the principal axis, the refracted ray ____

2. In a diverging lens, if an incident ray is parallel to the principal axis, the refracted ray ____

3. Can a real image be obtained by means of a diverging lens? If yes, how?

4. Draw a clearly labeled diagram showing the objects and images formed by a combination of a converging and diverging lenses.

Experiment No. 13

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

DATA SHEET

Unit 1:

A. Focal length of a convex lens by plane mirror method:

No.	Position of		focal length f
	convex lens	pin	
1.			
2.			
3.			

Units 2 & 3:

B. Focal lengths of a convex lens and a concave lens by conjugate foci method:

No.	Position of				
	Light source S	Lens L_1	Screen G_1	Lens L_2	Screen G_2
1.					
2.					
3.					

No.	Convex lens			Concave lens		
	p_1	q_1	f_1	p_2	q_2	f_2
1.						
2.						
3.						

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Questions:

1. Define focal length, object distance and image distance.

2. Distinguish between a real and a virtual image.

3. What is meant by parallax?

4. What is the convention of signs for f, p and q?

5. Is the object distance for L_2 in Fig. 7 positive or negative? Explain.

Experiment No. 14
Diffraction Grating

Objectives:

To determine the wavelengths of spectrum lines by means of a diffraction grating.

Apparatus:

A diffraction grating, discharge tubes, two meter sticks, stands.

Theory:

This experiment demonstrates that a diffraction grating and meter sticks can enable us to measure wavelengths as small as those of visible light.

Consider two identical point sources, S_1 and S_2, maintaining a constant phase difference (zero phase difference in this case) at all times. The intensities and the wavelengths of the two sources are equal. Such sources are called **coherent**.

Let us consider the resultant of the waves reaching point P on the screen from the sources S_1 and S_2. The distance between the sources is d ($=S_1S_2$), the screen is at a distance L from the sources and the point P is at a distance y from point O which lies on the axis SO of the setup (Fig. 14.1). An arc S_1Q is drawn with P as the center and PS_1 as radius. If $L >> d$, arc S_1Q will approximately be a straight line perpendicular to S_2P. Further, S_1S_2 is perpendicular to SO. Thus angle $S_2S_1Q = PSO = \theta$.

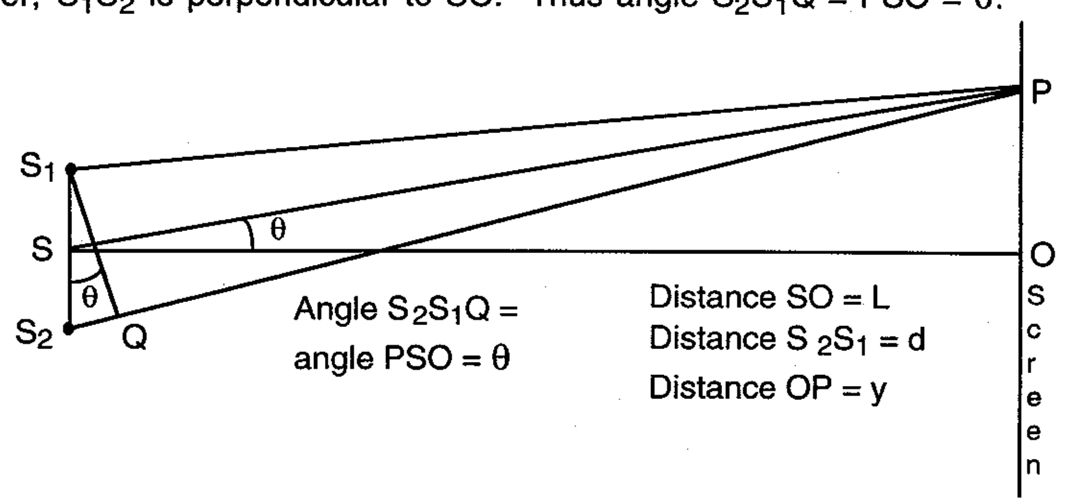


Fig. 14.1

The difference between the lengths of the two paths S_2P and S_1P is given by

path difference = $\overline{S_2P} - \overline{S_1P} = \overline{S_2Q} = \overline{S_2S_1} \sin\theta = d \sin\theta$.

If this path difference is equal to 0, λ, 2λ, 3λ, 4λ, etc., the two waves from S_1 and S_2 will arrive in the same phase at all times and will have constructive interference.

Further, if this path difference is equal to $\frac{1}{2}\lambda, \frac{3}{2}\lambda, \frac{5}{2}\lambda, \frac{7}{2}\lambda$, etc., the two waves from S_1 and S_2 will arrive in opposite phases at all times and will have destructive interference.

These conditions can be expressed as

$$d \sin\theta = m\lambda, \text{ for maxima} \qquad (1)$$

$$\text{and } d \sin\theta = \left(m + \frac{1}{2}\right)\lambda, \text{ for minima}$$

where m = 1, 2, 3, 4, etc.

We see from Fig. 14.1, that

$$\sin\theta = \frac{\overline{OP}}{\overline{SP}} = \frac{\overline{OP}}{\sqrt{\overline{SO}^2 + \overline{OP}^2}} = \frac{y}{\sqrt{L^2 + y^2}}.$$

Thus equation (1) can be written as

$$\frac{d\,y}{\sqrt{L^2 + y^2}} = m\lambda,$$

$$\text{or } \lambda = \frac{d\,y}{m\sqrt{L^2 + y^2}}, \quad m = 1, 2, 3, 4, \text{ etc.} \qquad (2)$$

m = 0, 1, 2, etc., give maxima of zero order, first order, second order, etc.

A diffraction grating consists of a large number of equally spaced identical slits. The distance between two corresponding points of a pair of adjacent slits is defined as the grating element d. Thus d is equal to the width of one slit and one spacing. If the condition for maximum is satisfied by the waves originating from two consecutive slits of the grating, it is satisfied by the waves originating from all other slits as well. Therefore, by measuring the positions of spectrum lines, wavelengths can be calculated by using equation (2).

It is obvious from equation (2) that if a source emits waves of different wavelengths $\lambda_1, \lambda_2, \lambda_3, \lambda_4$, etc., the maxima of a given order m will occur at different distances from point O. Thus a spectrum is obtained. Note that for the zero order, m = 0. Therefore, y = 0 for all wavelengths emitted by the source. Thus the central maximum (zero order) is of the same color as the source.

It should be pointed out that the condition for maximum of a certain order for a given wavelength is also satisfied if m in equation (1) is negative. Thus maxima of different orders for all wavelengths are formed on the other side of the central maximum as well. The light sources used in this experiment are discharge tubes containing hydrogen, helium, neon, mercury vapor, etc.

The electrons of atoms of the gases receive energy from the high voltage source and become excited, that is, attain higher energy levels. When the electrons return to lower energy levels, they radiate energy in the form of light. The light emitted in this process has discrete frequencies (wavelengths) that are characteristic of the emitting atoms. Thus the line spectra obtained are characteristic of the atoms. Molecules emit more complex spectra on being suitably excited.

Procedure:

(a) Fix a meter stick in the horizontal position and set a discharge tube vertically at the midpoint (S) of the meter stick as shown in Fig. 14.2.

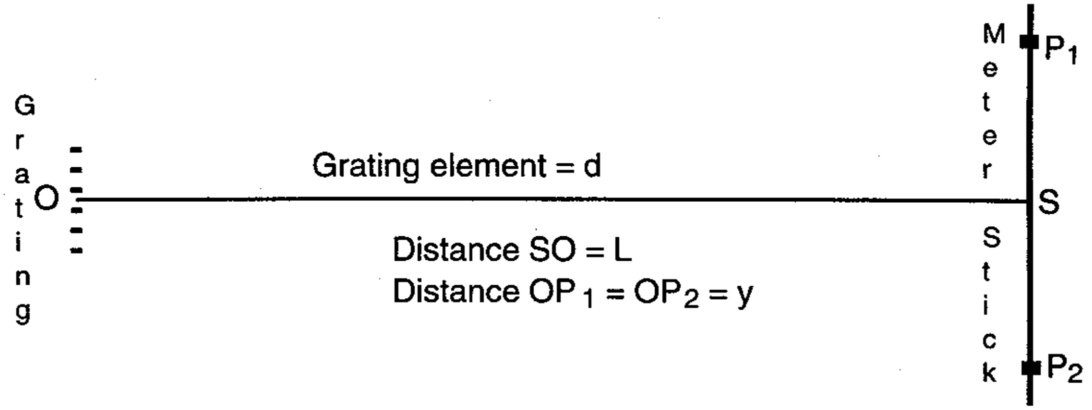


Fig. 14.2

(b) Mount the grating at a suitable distance (about 50 cm) from the meter stick such that the lines of the grating are vertical (parallel to the length of the discharge tube) and the plane of the grating is perpendicular to the central axis (line OS) of the setup. On looking through the grating, spectrum lines will be seen on both sides of the central maximum. Make sure that the spectrum is in the horizontal plane and it is symmetrical with respect to the central maximum. Also adjust the distance between the source and grating such that 2 or 3 brightest lines of first and second orders of the spectra fall within the extent of the meter stick. Measure the distance between the grating and the meter stick.

(c) Looking through the grating, read the position of the central maximum on the meter stick. Also read the positions of 2 lines of the spectrum on either side of the central maximum in the first order. Then read the positions of the same 2 lines in the second order on both sides of the central maximum.

(d) Repeat the procedure with the discharge tube of a different gas.

Precaution: Be careful in handling the high voltage source. Do not touch any part of the source or its mount when the power is on. Keep the discharge tube on only while taking readings. Do not keep it on for more than a minute at a stretch.

York College of The City University of New York

Physics II   Name:

Experiment No. 14: Pre-Lab Questionnaire

1. What is meant by the grating element (grating spacing)? Find the grating element of a grating having 12000 lines per inch.

2. Why is the zero order (central maximum) of the same color as the source?

3. For a given n (order), the lines of ____________________ wavelengths are closer to the central maximum.

4. How would you ensure that the lines of the grating are parallel to the length of the discharge tube?

5. How would you ensure that the plane of the grating is perpendicular to the central axis of the setup?

Experiment No. 14

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Experiment No. 14
Data Sheet

Observations:

Number of lines per inch on the grating =

Number of lines per cm on the grating =

Grating element d = cm

Source No. 1:

Distance of the meter stick from the grating, L = cm

Position of zero order, r_o = cm

Measure the same two lines in both (first and second) orders.

Line No.	Color	Order m	Position of the line (cm)		Distance of the line y (cm)		
			Left (r_1)	Right (r_2)	$y_1 = r_o - r_1$	$y_2 = r_2 - r_o$	Average
1		1					
2		1					
1		2					
2		2					

Source No. 2:

Distance of the meter stick from the grating, L = cm

Position of zero order, r_o = cm

Measure the same two lines in both (first and second) orders.

Line No.	Color	Order m	Position of the line (cm)		Distance of the line y (cm)		
			Left (r_1)	Right (r_2)	$y_1 = r_o - r_1$	$y_2 = r_2 - r_o$	Average
1		1					
2		1					
1		2					
2		2					

Calculations:

Grating element d = cm

Source No. 1:

Distance of the meter stick from the grating, L = cm

Line No.	Order m	Average y	Wavelength (nm)		Percent difference
			Observed [Eq. (2)]	Standard	
1	1				
2	1				
1	2				
2	2				

Source No. 2:

Distance of the meter stick from the grating, L = cm

Line No.	Order m	Average y	Wavelength (nm)		Percent difference
			Observed [Eq. (2)]	Standard	
1	1				
2	1				
1	2				
2	2				

Questions:

1. What is meant by coherent sources of light? Why can't we observe interference by using two lamps placed near two slits?

2. Why do the lines of different colors appear at different positions in the grating spectrum?

3. What is the sequence of colors in a grating spectrum? How does a grating spectrum differ from a prism spectrum?

4. Do you observe a real or a virtual spectrum at the meter stick? Explain.

5. How does the separation between two spectrum lines change with the order of the spectrum?

Experiment No. 15
Introduction To Digital Circuits
Logic Gates

by Drs. E. M. Levin and D. C. Jain

Objective:

(a) To introduce binary algebra.

(b) To construct simple gate circuits from diodes and resistors.

(c) To introduce truth tables for AND and OR gates.

(d) To introduce integrated circuits.

Apparatus:

2 silicon diodes, 1 LED, breadboard, 5-volt power supply, 1000 ohm and 220 ohm resistors, one AND-gate unit, one OR-gate unit.

A vacuum diode, shown schematically in Fig. 1a, is a vacuum tube consisting of 2 electrodes, a cathode C and a plate P, sealed in an evacuated envelope. The cathode C is heated by the filament F to give off electrons. The electrons are accelerated towards the plate P which is kept at a high positive potential with respect to the cathode. Thus the plate current is appreciable. On the other hand, if the plate voltage is negative, the plate current is negligible.

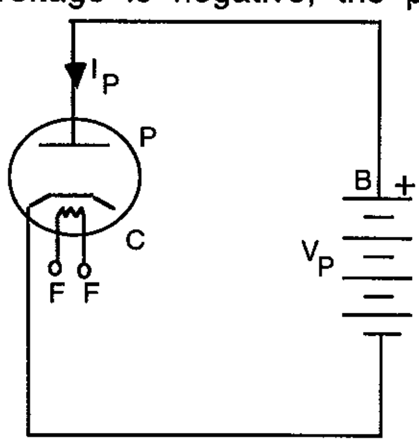


Fig. 1a.
A Vacuum Diode Circuit

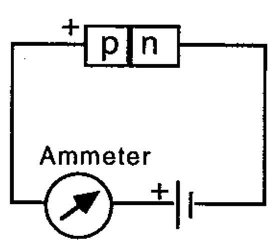


Fig. 1b
Forward-biased
pn junction

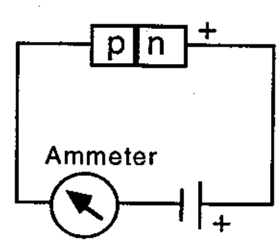
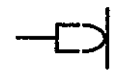


Fig. 1c
Reverse-biased
pn junction

A semiconductor diode works in a similar manner. A pn junction diode consists of p-type semiconductor and n-type semiconductor. The charge carriers in p-type semiconductors are positively charged holes while the charge carriers in n-type semiconductors are electrons. Each hole is a site where an electron is missing. A forward-biased pn junction diode, shown in Fig. 1b, allows a larger current than the reverse-biased pn junction which is shown in Fig. 1c. The resistance of a semiconductor diode in the forward direction is only about 100 ohms, though it requires about 0.6 volts to start the current. In the backward direction, it offers a large resistance (about 1 megohm) and effectively blocks the current.

We use the following symbols:

A semiconductor diode



A light-emitting diode (LED)

Background:

Binary Arithmetic:

An arithmetic that works with only two digits, 0 and 1, is called the binary arithmetic. It is ideal for use with computers which carry out complex procedures by rapid, successive operations involving two-state (on and off) logic gates.

Logic Gates:

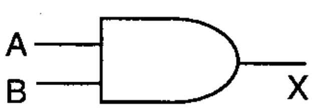
The logic gates are decision-making devices. They are the basic units of digital devices such as computers and electronic wristwatches. In this experiment, we will study AND and OR logic gates constructed with silicon diodes and resistors.

A two-input AND gate, with its output normally in the OFF [0] state, switches to ON [1] state when both input, A and B, are in the ON state. This fact is illustrated by the truth table shown in Fig. 2a. The AND gate symbol is also shown in Fig. 2a. The listing of all possible arrangements of inputs and outputs is called a truth table.

A two-input OR gate, with its output normally OFF [0], produces an ON [1] output if either of its inputs is in the ON [1] state. Fig. 2b shows the truth table for the OR gate along with the OR gate symbol.

A	B	Output (A•B)
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table

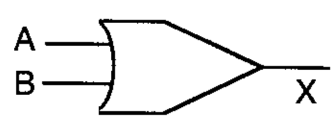


Symbol

Fig. 2a. AND Gate

A	B	Output (A+B)
0	0	0
0	1	1
1	0	1
1	1	1

Truth Table



Symbol

Fig. 2b. OR Gate

An AND logic gate can be constructed using two diodes, D_1 and D_2, and a resistor as shown in Fig. 3a. The arrows represent the forward direction (the direction in which they conduct) of the diodes. V_1 and V_2 represent the two input voltages. The operation of an AND gate is explained below.

When both input voltages, V_1 and V_2 (Fig. 3a) are zero, both diodes are conducting (have currents in them). Thus V_{out} is almost zero. Even with one of the input voltages zero, V_{out} is almost zero because the corresponding diode is conducting. When both input voltages are made positive, neither diode is conducting and V_{out} (= 5 volt) is applied to the LED circuit and it lights up.

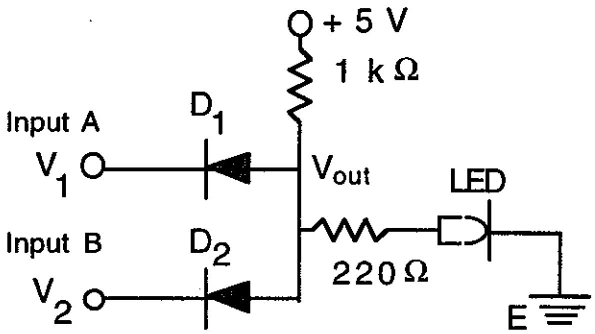


Fig. 3a
Schematic diagram of an AND gate

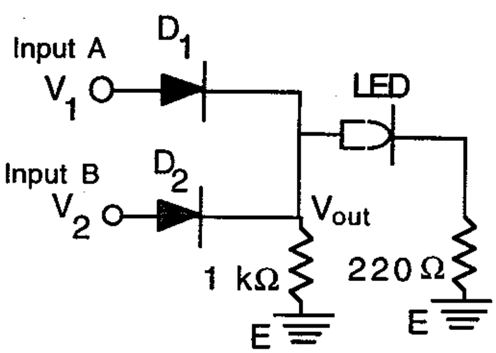


Fig. 3b
Schematic diagram of an OR gate

The schematic diagram of an OR gate is shown in Fig. 3b. In this case, if both input voltages are zero, the output voltage V_{out} is zero. When either of the input voltages are positive, one of the diodes is conducting. Consequently, V_{out} becomes positive and the LED lights up. Making the other input voltage positive does not alter the situation. This is how an OR gate operates.

In practice, miniature logic gates are fabricated on tiny silicon chips. Entire circuits can be printed on a chip so small that it is invisible to naked eye. Such a circuit is called an integrated circuit.

The breadboard to be used in this experiment is shown in Fig. 4. The lines indicate internal connections.

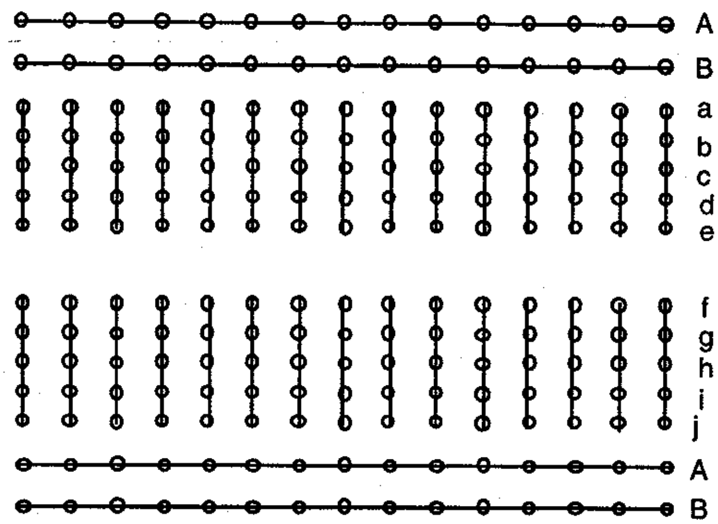


Fig. 4. Breadboard

Procedure:

Unit 1: AND Circuit:

In the following, row A and row B relate to the breadboard while input A and input B signify the inputs to the AND and OR gates. Points such as b2 and d1 indicate where the inputs A and B are applied to the gates.

(a) Make the circuit as shown in Fig. 3a using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground (negative of the power supply) to row A at the bottom. Remember that the silver end of the diode indicates the forward direction. Connect one diode between a2 (silver end) and a5, and the other diode between c1 (silver end) and c5. Connect the 1 KΩ resistor between row B (top) and b5. Connect the 220 Ω resistor between d5 and d7 and the LED between e7 and f7 (flat end). Connect j7 and row A (at the bottom). Input A is applied at b2 and input B, at d1.

(b) Connect both inputs, A (b2) and B (d1), to ground (A = 0 and B = 0) and fill in the output state (0 or 1) in the truth table (Data Sheet).

(c) Remove the wire connecting b2 to ground. Apply +5 V to input A (by connecting top B to b2) leaving input B grounded and write the output state in the truth table. Now apply +5 V to input B (by connecting top B to d1), connect input A (b2) to the ground and write the output state in the truth table. Finally, connect both inputs to +5 V and enter the output state in the truth table.

Unit 2: OR Circuit:

(d) Make the circuit as shown in Fig. 3b using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground (negative of the power supply) to row A at the bottom. Connect one diode between a2 and a5 (silver end) and the other diode between c1 and c5 (silver end). Connect the 1 KΩ resistor between e5 and f5. Connect the 220 Ω resistor between d5 and d7 and the LED between e7 and f7. Connect j7 and row A (at the bottom). Input A is applied at b2 and input B, at d1.

(e) Connect both inputs, A (b2) and B (d1), to ground (row A at the bottom). Thus input A = 0 and B = 0. Fill in the output state (0 or 1) in the truth table (Data Sheet).

(f) Apply +5 V to input A (by connecting top B to b2) leaving input B grounded and write the output state in the truth table. Now apply +5 V to input B (by connecting top B to d1), connect input A (b2) to the ground and write the output state in the truth table. Finally, connect both inputs to +5 V and enter the output state in the truth table.

Unit 3: OR To AND Circuit:

OR and AND gates can be connected to represent the following physical situation:

Consider a heavy safe that has to be carried. Two boys (Adam and Brad) together can not lift it. One man (Calvin) with the help of at least one boy can carry it. A truth table can be constructed to show all combinations of A, B and C. The states of A, B and C can be represented by 1 (working) and 0 (on a coffee break). The output column of the truth table will have 1 (if the safe can be moved) or 0 (if the safe can not be moved). This situation can be represented by a logic circuit shown in Fig. 5.

Instead of constructing the OR and AND gates using the diodes as in units 1 and 2, it is more convenient to employ commercial gates. Each commercial unit has four OR (or four AND) gates. There are fourteen pins in each unit. When the unit is mounted on the breadboard, its 7 pins are inserted in row e while the other 7 pins are inserted into row f. The recessed side should be on the left. Pin #14 (top left) receives the voltage (+5 V); pin #7 (bottom right) is connected to the ground. The inputs (A and B) and the output (x) of the first gate are pin #1, #2 and #3, respectively. The second gate is accessed by pins #4, #5 and #6, and so on and so forth.

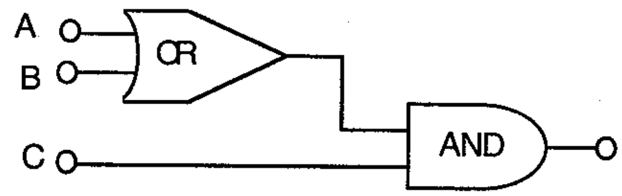


Fig. 5. OR to AND Circuit (Schematic)

(g) Make the circuit as shown in Fig. 6 using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground to row A at the bottom. Mount the OR-gate unit (7432) on the left side of the breadboard and the AND-gate unit (7408) on the right side. Connect pin #14 to top row B. Connect pin #7 of the OR unit to ground (bottom row A) and its pin #3 to pin #1 of the AND unit. Thus the output of the first OR gate will be fed to input A of the AND gate. The second input (B) for the AND gate will be fed to its pin #2. Connect a 220 Ω resistor and LED as shown in Fig. 6 below. Connect pins #14 of the OR-gate and the AND-gate unit to top row B of the breadboard and its pin #7 to the bottom row A (ground).

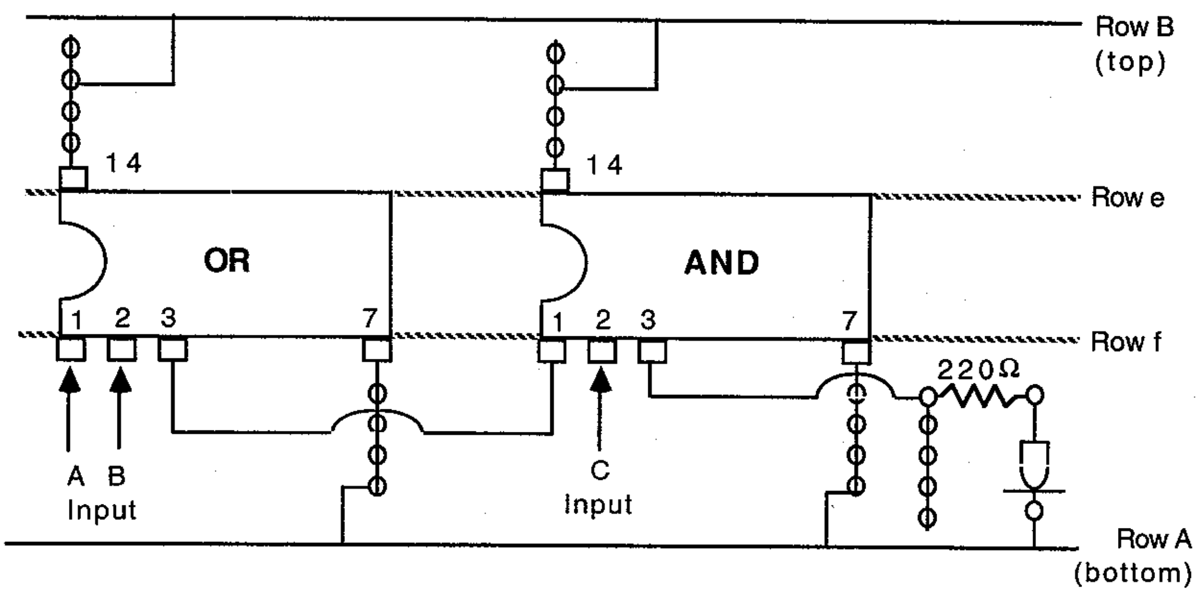


Fig. 6. OR To AND Combination Circuit.

(h) Apply different combinations of inputs to pin #1, pin #2 of the OR-gate unit and pin #2 of the AND-gate unit. Enter the output states in the truth table on the data sheet.

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Physics II

Name:

Experiment No. 15: Pre-Lab Questionnaire

1. Why does a forward-biased pn junction diode allow a larger current than a reverse-biased pn junction?

2. When do we obtain an ON [1] output from an AND gate?

3. When do we obtain an ON [1] output from an OR gate?

4. Briefly describe an integrated circuit.

5. How are the first two gates of a four-gate commercial unit accessed?

Experiment No. 15

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

Experiment 15. Introduction To Digital Circuits
DATA SHEET

Name: Partner:

Unit 1: Truth Table of AND Gate

Input states		Output state
A	B	X
0	0	
1	0	
0	1	
1	1	

Unit 2: Truth Table of OR Gate

Input states		Output state
A	B	X
0	0	
1	0	
0	1	
1	1	

Unit 3: Truth Table of OR To AND Gate

Input states			Output state
A	B	C	X
0	0	0	
1	0	0	
0	1	0	
1	1	0	
0	0	1	
1	0	1	
0	1	1	
1	1	1	

Appendix

Wavelengths of some lines of the spectrum:

Source	Color	Wavelength (nm)
Hydrogen	red	656
	blue	486
	violet	434
	violet	410
Helium	red	706
	red	667
	yellow	587
	blue	501
	blue	468
	violet	447
Mercury	red	734
	red	690
	orange	615
	yellow	578
	green	546
	violet	435