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A STUDY COMPARING TWO METHODS OF TEACHING BASIC ELECTRONICS

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A Thesis Submitted to the Graduate Division in Partial Fulfillment of the Requirements for the Degree of Master of Science

By

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CHAPTER I

INTRODUCTION

Orientation to the Problem

Due to the importance given to Electricity-Electronics in our society, and the increasing demand for well trained technicians in this area, there have been various attempts to improve the methods by which Electricity and Electronics are taught. New programs have been developed using visual aids, laboratory kits, programmed instructional material, experiments, demonstration equipment, and various other techniques. It has recently become popular to combine several of these vehicles and techniques of learning into a composite instruction unit, sometimes referred to as a "package program," containing text, laboratory manuals, and needed equipment. These programs are designed to provide an instructional media which is both economical and efficient.

At the present time equipment similar to that mentioned above is produced by over ten different companies. Several of these programs have been well accepted and are considered to have many attributes, however, their effectiveness as compared to the conventional "lecture-demonstration and project" method of instruction has not undergone investigation.

Statement of the Problem

The problem is to compare two methods of teaching basic electricity, one being the 3-E Experimenter method by McKnight and McKnight Co., and the other being the "lecture-demonstration and project" method used at the Kansas State College of Pittsburg to instruct the class "Applied Electricity 140."

The two methods will be compared according to the following criteria.

1. The students' level of initial learning.
2. Project construction quality
3. Project reports
4. Direct observation

Need for the Study

The needs for the proposed study are:

1. The need of added information for colleges, high schools, and junior high schools concerning the effectiveness, advantages, and disadvantages of the 3-E Experimenter, and the "package program" method of instruction.
2. The need for information for the Industrial Education and Art Department of Kansas State College of Pittsburg concerning the effectiveness of the McKnight 3-E Experimenter, and other similar methods of teaching basic electricity, as compared to the "lecture-demonstration and project" method now in use.

Limitations of the Study

The proposed study is limited to:

1. The course "Applied Electricity 140," offered at Kansas State College of Pittsburg.
2. The spring term of the 1964-1965 school year.
3. The 3-E Experimenter and "Lecture-Demonstration and Project" methods of teaching basic electricity.
4. The criteria listed in the statement of the problem.
5. The conditions and environment under which the study is to be conducted.
6. The material covered in the first three chapters of the 3-E program.

Definition of Terms

3-E Program. The 3-E program (Energy, Electricity, and Electronics) consists of the textbook *Energy, Electricity and Electronics*, a laboratory manual, a professional edition of the textbook, an applied activities book, plus the 3-E Experimenter units.

> This program provides complete coverage of text-experiment content for basic electricity and electronics. It provides (A) theoretical and technical information; (B) learning by "doing" through experimentation and construction; (C) specific notations for the teacher. The experimental equipment has been developed to meet the full requirements of a text-oriented course. (McKnight and McKnight, 1964, p. 18)

3-E Experimenter. A set of five units used for the performance of experiments outlined in the laboratory manual and to provide reinforcement of theory and technical information covered in the textbook, *Energy, Electricity, and Electronics*.

Package Program. A prepared means of instruction which is designed to provide a course outline and most, if not all, the equipment and reference material needed to teach a specific subject. The equipment is usually designed to provide an illustration, or direct application, of the material studied, and is considered essential to the learning process.

Parallel-Group Technique. A procedure where two groups of nearly equal ability are used in an experimental situation. Conditions of the situation are controlled as carefully as possible, except for one variable or experimental factor, which is varied for one group (the experimental group). The other group (the controlled group) is used for comparative purposes, undergoing customary or non-experimental conditions. (Good and Scates, 1954, p. 705)

Review of the Literature

Although there appears to ae an absence of studies directly related to the present study, there is considerable information explaining the problems which now exist in the teaching of basic electricity-electronics, which in turn

influenced the development of new instructional methods, such as the "package program." Buban (1963) mentions that the teaching of electricity-electronics usually involves several problems which are as follows:

1. There is a need for a closer relationship between industry and industrial education.

2. Electricity-electronics courses should offer both theory and practical work.

3. Students need a vast range of information.

4. The instruction of this subject will require more time than other industrial arts courses.

The recent advancements in electricity-electronics have made it difficult for the electricity teacher to keep his program abreast of present trends and developments. The expansion of knowledge in the field has become so extended that the instructor must beware of spending too much time on any one segment of the vast amount of material to be presented. If the electricity student is to receive a comprehensive and complete introduction to the subject, provisions must be made so that instruction can take place more effectively.

Writers interested in the improvement of industrial education have drawn attention to the need for improved teaching methods and the importance of added research to determine of what these desired methods consist. This belief is expressed in an article by Brown (1963) who made the following comment:

> Additional research must be conducted to determine the most effective method of teaching.

In considering the ideal method of instruction, Gerrish (1963), expressed the following opinion:

> The desired approach is one in which the most effective, easiest-to-administer method is used. The project, quick connection, and project analysis are three possible methods.

The question of effectiveness, with reference to methods of instruction, has received considerable attention. The "project" method, commonly used in many industrial arts programs and considered by many to be adequately effective, is described by Brown (1963) as producing a retainable product, but one that is usually high in cost, is of little use, contains poor workmanship, and presents the problem of supplying parts for its construction.

McEachern (1963), in his study "Teacher Demonstration Versus Shop Activities," found no significant difference in the teaching effectiveness of the "teacher-demonstration" and "shop activities" method. His study compared the information achievement and attitude toward the class of a control group which devoted its laboratory time to making selected projects, and an experimental group whose laboratory time was used observing "teacher-demonstrations." McEachern stated the implications of his findings in the following statement:

> The findings imply that students in a definite, planned course in basic electricity will learn approximately the same amount of information content if taught by either instructional method, teacher-demonstration or student activity. Students' attitudes will not be effected significantly if taught by either teacher-demonstration or student activity instructional methods.

Suess (1961) studied the effectiveness of "student-activities," with reference to the act of handling objects in a constructive, exploratory, or exploritative way. He reported a significant difference in initial learning and retention as compared to students not experiencing manipulative treatment. The study investigated the effect of object manipulation on the directed discovery method of teaching technical information which, in his study, involved the basic principles of orthographic projection. Although student manipulation activities could not be accredited as having a significant effect on initial learning, the mean achievement of treated students was reported to be consistently higher than students not experiencing manipulative activities.

In contrast to evidence indicating otherwise, Good (1959) defines the principle of "student-activities" to be as follows:

> The principle that children learn most readily and retain longest those things which they learn by themselves of their own accord through manipulation, contrasted with vicarious or externally motivated learning; does not preclude guidance by the teacher, but does preclude teacher domination.

The effectiveness of the project, demonstration, and lecture methods, in this writers opinion, is not so much under question as are the programs and procedures by which they are utilized.

Considering more recently developed instructional media, some attention should be given to conducted research involving closed circuit television and programmed instruction.

Horning (1964) compared the effectiveness of a televised demonstration to a conventional "face-to-face demonstration." The learning task was "trouble shooting" with a Simpson Volt-Ohm-Meter. Treatment was given to two parallel groups of equal knowledge and background. The following statement was made in the conclusion of the study:

> The presentation of the demonstration on trouble-shooting with the Simpson Volt-Ohm-Meter was effective by the media of closed-circuit television as it was by the conventional face-to-face class demonstration.

Householder (1963) investigated the effectiveness of programmed instruction in the teaching of orthographic projection. From his findings it was concluded that effective presentation of information can result from the utilization of a "programmed" textbook.

In an article on the subject of programmed instruction Barnard (1963) comments that it has the potential of lightening the teacher work load, permitting greater individual student progression, teaching fundamentals in less time, and broadening the industrial arts curriculum by making instruction available that has usually been deleted due to the instructors lack of time and training.

The "package program" involving the use of "quick connection" equipment is another of the more recent developments in the use of the "lecture-demonstration, and project methods" of instruction. An article by Brown (1963) describes "quick-connection" equipment to be as follows:

> The (quick-connection) method; introduced connecting a partical circuit, filling in a laboratory manual, and returning parts to storage.

He also expressed the opinion that one of the main advantages of this method is low student cost, the disadvantages being: excessive time and effort spent in keeping track of parts, students are often limited to manuals, and programs are often commercialized or educationally unsound.

One of the more recent developments in the instruction of basic electricity-electronics is the "3-E Experimenter" program produced by the McKnight and McKnight Company. This system offers the type of instruction with which the proposed study is directly concerned. It appears to contain most of the necessities found in a "package-program" in that it provides the reference material and equipment needed to offer a basic electricity-electronics course. It differs from some package programs by recommending project construction activities to accompany the "lecture-demonstration and experiment methods" of instruction. The authors Miller and Culpepper (1964) further recommended that one-third of the total class time be devoted to each of the three methods of instruction, being lecture-demonstration, experiments, and project construction.

Although the structure and design of the 3-E Experimenter, and other similar programs, appear to be founded upon sound educational theory, a review of the related literature provides a dearth of investigations to illustrate

the effectiveness and operational characteristics of such instructional media.

In giving further consideration to this matter, Brown (1963), made the following comment:

> Considerable educational research needs to be completed to prove effectiveness. Until the research is completed caution should be exercised in the wholesale adoption of programmed package equipment.

With due consideration for related research, comments, developments, and our need for improved educational methods, it is this writers opinion that Barnard (1963) adequately expressed the need and reason for the proposed study in the following statement:

> Clearly, industrial arts and vocational education leaders have a challenge and a responsibility to write and test programs, and the teachers in the field have a similar responsibility to utilize the materials once they are available.

Statement of Hypotheses

1. There is no significant difference of initial learning levels between treatments as measured by the electricity-electronics test developed for the present study.
2. There is no significant difference in the construction quality of projects.
3. There is no significant difference in the quality of project reports.

CHAPTER II

THE EXPERIMENT

The Learning Task

Treatment was administered during forty and fifty minute class periods of the course "Applied Electricity 140" at Kansas State College of Pittsburg, starting on February 16 and ending on April 21, 1965. Classes met from 8:30 until 9:20, Monday through Friday. The lecture rooms, experimentation area, and industrial arts shop were all part of the plant facilities of the electricity-electronics section in the Department of Industrial Education and Art at Kansas State College of Pittsburg.

All subjects enrolled in the course, "Applied Electricity 140," had the standard text Basic Electricity (Turner, 1961), and the syllabus for the course. Each student completed a required volt-ohm-milliammeter project which included the writing of an extensive project report.

The material presented in the treatments of the study consisted of the information contained in the first three chapters of the McKnight and McKnight 3-E program which are entitled as follows: a. Nature of Electricity b. Magnetism c. Electrical Measuring Instruments.

The selection of the learning material was influenced by the limitations of time, equipment, and available facilities needed for the study. It was necessary that the study

be completed during the Spring Semester, 1965 which limited the amount of information that could be adequately covered in the study.

Treatment A and B contained the same basic fundamentals of electricity-electronics. Treatment A was administered to group A via the 3-E program and treatment B was administered to group B via the "lecture-demonstration and project method."

On April 21, the presentation of treatments A and B was completed. At this point both groups had received apparently equal amounts of subject matter. After this date, all subjects were returned to their original status and advanced in the course under normal conditions.

With the completion of the project reports, due on April 28, it was felt that each group had received equal benefit from the project. Although there were students in both groups who had not fully completed their projects, the remaining final assembly steps were not considered of primary importance to the initial learning of the students. The postest to sample the students initial learning was given at 8:30 on April 29.

Treatment A was administered to group A by the writer using the 3-E program which utilized the "lecture-demonstration, project, and student experimentation methods of instruction." It also provided a professional edition of the text for the instruction which was identical in content to the

student text but had in addition a margin on each page containing teaching suggestions such as: points to emphasize, possible visual aids, films, and related experiments found in the 3-E workbook.

Treatment was administered during class periods of "Applied Electricity 140" which met Monday through Friday from 8:30 a.m. to 9:30 a.m. Although the normal class period was fifty minutes, several classes were shortened or dismissed to allow for special school activities and events. Situations of this kind were equal to both groups A and B.

Treatment A consisted of the following time break down: lecture-demonstration 1,170 minutes, student experimentation 450 minutes, and project construction 215 minutes. The total time of treatment was 1,835 minutes. The total time is inclusive of the time given to taking role, making announcements and other miscellaneous activities which cannot actually be referred to as formal instruction.

The different instructional activities were scheduled according to the treatment outline found in (APPENDIX C). The time given to lecture-demonstration, experimentation, and project construction during a single class period was influenced by the students progress, interest, and instructional needs as observed by the instructor.

The course outline for treatment A contained the information presented in the first three chapters of the 3-E text (APPENDIX A) and the first ten experiments in the 3-E

workbook. (APPENDIX B) These experiments required only the use of experimenter units "one" and "two." The AC-DC power unit was not needed due to the availability of similar power supplies at the college.

The authors of the 3-E program, Miller and Culpepper, (1964), recommend that not more than two students should use a set of units at one time. Due to research conditions, the students experimentation activities were conducted simultaneously. Seven sets of experimenter units "one" and "two" were used by group A which consisted of sixteen students. In two cases three students were assigned to a set of units. The units were numbered and assigned to pairs or groups of students who used the same units throughout the study. The sixteen students were divided into seven groups, with a set of units being assigned to each.

The seven sets of the 3-E Experimenter units were obtained as follows: one set was furnished by the college and six sets were supplied by the McKnight and McKnight Co. The 3-E text was given as the primary reference for group A, however, the original text Turner (1961) was also used.

Students in group A did not take part in project construction until the introduction of "electrical measuring instruments" was begun. At this point project construction activities were integrated into the existing lecture-demonstration and student experimentation methods of instruction.

Treatment B was administered to group B by the electricity-

electronics instructor at Kansas State College of Pittsburg using the "lecture-demonstration and project method of instruction." Treatment B represented the program normally presented to the class "Applied Electricity 140" at Kansas State College of Pittsburg. The original course outline (APPENDIX E) was modified for the period of the experiment so that Treatment A and Treatment B contained the same electricity-electronic fundamentals.

Subjects in group B used the normal text for the course Basic Electricity by Turner, (1961), in addition to the suggested references found in the course syllabus. These references were also available to group A.

Treatment was administered during class periods of "Applied Electricity 140" which met on Monday through Friday from 8:30 a.m. to 9:30 a.m. Although the normal class period was fifty minutes, several classes were shortened or dismissed to allow for special school activities or events.

Subjects received treatment by the "lecture-demonstration" method on Monday, Wednesday, and Friday. The Tuesday and Thursday class periods were primarily devoted to project construction activities. Included in the project construction activities was the enactment of a student personnel plan which placed definite shop responsibilities on four different students. The student personnel assignments were rotated every two weeks. The student activities and responsibilities involved in this system are found in APPENDIX E.

Treatment B consisted of the following time break down: lecture-demonstration 1,115 and project construction time 720 minutes, which also included demonstrations on the use of shop equipment. The total time of treatment was 1,835 minutes. As was reported in the discussion of Treatment A, this figure of total instruction time is inclusive of the time given to taking role, making announcements, and other miscellaneous activities which cannot actually be referred to as formal instruction.

Treatment B was presented according to the modified course syllabus found in APPENDIX D.

Students in group B began project construction activities with the start of Treatment B, however, during the earlier phase of treatment, part of the project construction time was devoted to talks and demonstrations on equipment and instruments.

The Project

Included in Treatment A and B was the construction of a volt-ohm-milliammeter. (APPENDIX F) The project was designed by Mr. A. O. Brown III, Electricity-Electronics instructor at Kansas State College of Pittsburg, for the purpose of providing an effective means of applying the theoretical information presented in the course "Applied Electricity 140." In addition to its educational value, the project had the potential of being very useful to the

student when completed. Student construction cost was minimized by ordering parts in quantity through the school.

A project report was required of each student which was to be outlined as follows: description, use, how it worked, schematic drawing, parts list, price list, and construction procedure.

The basic meter design, circuit board layout, schematic breakdown, parts list, and price list were given to the student to reduce construction time. (APPENDIX H) Students were free to modify the basic meter design if they so desired. Although there were definite educational advantages to be obtained by having each student completely design his own meter, it was felt that such a process would involve inefficient use of class time and would also require information and knowledge beyond the objectives of the course.

Students were required to determine the value of the dropping and shunt resistors needed for the meter. The assignment of the project report also aided students in developing an understanding of the electrical theory involved in the various functions of a volt-ohm-milliammeter.

April 28 was set as the date on which the project reports were due. At this point, with the reports written and only the final assembly steps remaining, the students were considered to have obtained most of the educational value for which the project was intended. However, it is difficult to define the education received by some students

as they went through trouble shooting procedures when their meters at first failed to function properly.

Further information on the meter, and the project material presented to the students may be found in APPENDIX F.

Population and Sampling

The subjects in the present study were students enrolled in "Applied Electricity 140" at Kansas State College of Pittsburg. The population totaled thirty-two students which were randomly assigned to groups A and B. The Lorge-Thorndike Intelligence Test and a comprehensive electricity-electronics test were administered to the population to check the validity of the random selection. Raw scores on the Lorge-Thorndike Intelligence Test were obtained from all students, however, raw scores on the comprehensive electricity-electronics test were not obtained for two students. Although the selected groups remained intact throughout the study, at this point the sampling for the study provided thirty students.

Another requirement which placed a limit on the final number of subjects was that all subjects had to be taking the course for the first time. It was also necessary that all subjects be present for the final testing session. Of the remaining sample, one student was repeating the course and one was absent on the day the posttest was administered.

The final twenty-eight subjects who completed the experimental treatment and testing sessions may be defined

as: students attending Kansas State College of Pittsburg during the spring semester of 1965 who were enrolled in "Applied Electricity 140", who had been previously tested for intelligence and previous knowledge of basic electricity-electronics, and who had not previously taken the course "Applied Electricity 140" at Kansas State College of Pittsburg. Table I gives a summary of the final population and the deletion of the subjects who did not fit the definition.

TABLE I

DETERMINATION OF THE EXPERIMENTAL POPULATION FROM THE TOTAL STUDENT ENROLLMENT IN APPLIED ELECTRICITY 140

A. Total enrollment of the class		32
B. Excluded from the experimental population		
1. Lack of L. T. I. T. or C. E. T. scores		
a. Absent during test sessions	2	
b. Foreign student with language problem	1	
2. Repeating the course	1	
C. Resultant experimental population		28

Evaluation Instruments

To check the validity of the random selection forming groups A and B, the Lorge-Thorndike Intelligence Test and a comprehensive electricity-electronics test were administered

to the population. Both were paper and pencil tests and were administered during separate fifty minute class periods. The electricity-electronics test was also used as a posttest to obtain measures of initial learning.

The electricity-electronics test was developed by the writer using as a guide the test questions previously used in the course "Applied Electricity 140", however, none of the previously used questions were duplicated.

The test contained ninety-two best answer multiple choice questions as are discussed in Micheels and Karns, (1950). The test was designed to give an indication of the students knowledge and understanding of the basic principles of concepts presented during treatments _A_ and _B_. Questions selected for use in the test were divided into four main subject areas which were as follows: general electricity, magnetism, measuring instruments and devices, and questions requiring graphic illustration. The questions were then randomly distributed to formulate the test.

Prior to the time of the study an earlier form of the test was given to a class of advanced electricity-electronic students who were asked to answer the questions and make any comments they felt necessary for the improvement of the test. The test results were then examined and consideration was given to the student's comments and to questions that were missed excessively. The evaluation instrument may be seen in APPENDIX G.

Experimental Design

Due to the limited conditions under which the study was conducted, the experimental design used was a modification of "Design 4," "the Pretest-Posttest Control Group Design," as discussed by Campbell and Standly (1963). In adapting "Design 4" (as presented in Fig. 1) to the conditions of the present study, consideration was given to the fact that both groups received treatment thus eliminating the existence of a control group.

R O_1	X	O_2
R O_3		O_4

R = randomization
X = treatment
O = observation

Fig. 1
Design 4, Campbell and Stanley, (1963)

"Design 4" was therefore modified to the design represented in Fig. 2.

R O_{ab}	$X_{\underline{A}}$	O_b
R O_{ab}	$X_{\underline{B}}$	O_b

A = treatment by 3-E method
B = treatment by the traditional method at KSC of Pittsburg
a = Lorge-Thorndike Intelligence Test
b = electricity-electronics test

Fig. 2
Modification of Design 4

In the present study two parallel groups were randomly selected from the population and assigned to treatment A and B. To check the equivalence of the experimental groups, an analysis of variance was computed on the means of scores on the Lorge-Thorndike Intelligence Test and scores on the electricity-electronics test which was developed by the writer for use in the study.

TABLE II

MEANS AND STANDARD DEVIATIONS OF PRETEST SCORES ON THE LORGE-THORNDIKE INTELLIGENCE TEST AND THE ELECTRICITY-ELECTRONIC TEST, AND THE NUMBER OF STUDENTS USED IN THE FINAL ANALYSIS OF TREATMENT

	Lorge-Thorndike Intelligence Test			Electricity-Electronics Test		
	X	σ	N	X	σ	N
Group A	51.7	6.2	15	44.6	10.5	15
Group B	54.7	7.5	13	50.4	10.9	13
		Total	28			28

TABLE III

ANALYSIS OF VARIANCE OF PRETEST SCORES ON THE LORGE-THORNDIKE INTELLIGENCE TEST OF THE SUBJECTS USED IN THE FINAL ANALYSIS OF TREATMENT

Source	d. f.	ss_X	Means Sq.	F.
Between groups	1	61	61	1.52*
Within groups	26	1045	40	
Total	27	1106		

* F. at the .05 level = 4.22

F. at the .01 level - 7.68

TABLE IV

ANALYSIS OF VARIANCE OF PRETEST SCORES ON THE ELECTRICITY-ELECTRONICS TEST OF THE SUBJECTS USED IN THE FINAL ANALYSIS OF TREATMENT

Source	d.f.	ss_X	Means Sq.	F.
Between groups	1	232	232	1.78
Within groups	26	3373	130	
Total	27	3605		

A block diagram of the final experimental design is presented if Fig. 3 on page 24.

Class of
Applied Electricity 140

PRETEST

RANDOM SELECTION

of

GROUPS

Lorge-Thorndike
Intelligence Test
and
Electricity-Electronics
Test

TREATMENT A

Lecture-Demnnstration
Student Experimentation

via

3-E Program

TREATMENT B

Lecture-Demonstration
Project Construction

via

Traditional Method
at
KSC of Pittsburg

POSTTEST

Electricity-Electronics
Test

Fig. 3
Block Diagram of Experimental Design

Recording and Analysis of Data

The comparison of the two methods was based on data supplied from the following sources:

Test

a. Pretest scores
b. Posttest scores

Direct Observations

a. Shop activities
b. Problems encountered while using the 3-E program
c. Recorded observations during treatments.

Statistical analysis was only applied to data obtained from pretest and posttest scores. All other data was recorded during the study with the intention that it would be of value to those interested in using or improving the 3-E program. To aid in the recording of comments and observations, a daily observation form was prepared which may be seen in APPENDIX J.

A desk calculator was used to compute the statistical data for $\bar{X}$, s, ΣX, ΣY, ΣX^2, ΣY^2, and ΣXY. These computations were performed on pretest and posttest scores to test for a significant ratio between means, with F. at the .05 level.

As can be seen in Tables III and IV, an analysis of pretest scores indicated that the groups did not differ significantly in intelligence or knowledge of electricity.

CHAPTER III

RESULTS AND DISCUSSION

Statistical Results

Table V (APPENDIX K) presents each student's score on the Lorge-Thorndike Intelligence Test and each subject's pretest and posttest score on the electricity-electronics test.

Table VI (APPENDIX K) represents the group means of initial learning scores and the difference in pretest and posttest means from scores on the electricity-electronics test.

Test of Hypotheses

Hypothesis 1 was tested by computing an analysis of variance between test scores of initial learning. Hypotheses 2 - 3 were tested on observations made by the instructors of the study.

Test of Hypothesis 1

Hypothesis 1: There is no significant difference of initial learning levels between treatments as measured by the electricity-electronics test developed for the present study.

An analysis of variance was computed from scores on the initial learning test. The mean square ratio from this analysis yielded a non-significant F of .96 with the probabilities of attaining significance at the .05 and .01 levels equal to 4.22 and 7.72 respectively as indicated in the footnotes of Table VII.

On the basis of variance between means of posttest scores, the hypothesis of equal means must be accepted.

Test of Hypothesis 2

Hypothesis 2: There is no observable difference in the construction quality of projects.

Observations made by the instructors used in the study found no difference in quality of project construction or student workmanship. Although not vivid, it appeared that subjects given treatment B were more conscious of meter accuracy than subjects given treatment A.

Test of Hypothesis 3

Hypothesis 3: There is no observable difference in the quality of project reports.

Project reports were analyzed according to the following criteria:

1. Use of the outline form recommended in the course syllabus which may be seen in APPENDIX F.
2. Quality of describing how the meter works with respect to electrical instrumentation theory presented during treatments.
3. The completeness of the report with respect to the inclusion of an adequate description of the following:
   a. Description of the project
   b. The use of the meter
   c. How the meter works and the electrical principles involved
   d. Complete parts and price list of componets

e. Construction procedure

f. Graphic presentation of dimensions, circuit schematic, and parts placement.

No signicant difference in groups could be detected from the evaluation process. A wide range in quality of presentation was found in both groups. A generalized difference in groups did not noticeably exist. Under these conditions, hypothesis 3 must be accepted.

Observations Recorded While Using the 3-E Program

In considering the following observations it is important that the reader take into consideration the limitations listed in CHAPTER IV. These observations are reported in hopes that they will be of value to those interested in the 3-E program or programs of close similarity. Unless stated otherwide the following observations are reported on the basis of their considered importance and not on their frequency of occurrence.

1. The professional edition of the 3-E test is of assistance to the instructor in developing a course of study.

2. While conducting experiments requiring the use of a power supply, it was observed that students occasionally shorted out the power supply which usually resulted in a blown fuse or more serious damage to the unit.

3. Some students appeared to have a tendency to prove in an experimental manner on circuit boards in search of a desired response after their initial attempts had failed.

4. Students with greater mental ability and background in electricity-electronics were observed to finish the assigned experiments ahead of less capable students. Exceptions were noticed when advanced students became unusually interested in the content of a specific experiment.

5. The 3-E workbook provides both a schematic and a pictorial drawing of the circuits needed to conduct a given experiment. It was observed that students had a tendency to follow the pictorial drawing more than the schematic.

6. When giving a lecture, it appeared that a better line of communication was established between the students and the instructor when reference could be made to an experiment previously conducted by the students which was of direct relation to the information being presented.

7. In lecture sessions students asked questions which appeared to have originated from their experimentation activities.

8. In a few cases students reported that they had conducted similar experiments in high school physics classes.

9. Some students asked for additional sources of information on subjects presented in the 3-E text.

10. In the present study it was necessary to lecture in one class room and conduct experimentation in another. It was observed that when lecture-demonstration and experimentation activities were involved in the same class period, the time required to change from one instructional situation to another was not minimized unless the class was well organized and students were motivated.

Suggestions

The following suggestions are based upon and limited to the observations recorded during the present study.

1. It is recommended that the instructor have activities of true educational value planned for students who finish an assigned experiment ahead of the anticipated schedule.
2. To reduce the loss of parts and equipment it is suggested that experiment units and their related componets be administered and collected at each class period by the instructor. Students should receive only the componets needed to conduct the experiments in the chapter currently being studied.
3. Students need to be instructed on the proper use of V.O.M., AC-DC power supply, and the meters contained in the experimenter units before they start experiments requiring the use of these devices.

4. If a substitute is made for the 3-E power supply, it is recommended that the unit contain an overload protective device and also be relatively simple to operate. The voltage and current capacity of the unit should be close to that of the 3-E power supply unit.

5. All meters available for student use should contain a protective device.

6. If possible the instructor should conduct each experiment personally before assigning it to the students. This process would enable the teacher to be more aware of the material, activities, and experiences to be encountered by the students.

7. It is recommended that students be given a list of references which can be used to obtain a more technical and scientific overview of the material presented in the 3-E text.

8. It is suggested that students be encouraged to draw circuits diagrams when they are confused as to why a certain circuit they have wired does not produce the correct response.

9. It is recommended that the instructor give students an opportunity to discuss recently completed experiments.

10. It appears that the 3-E Experimenter units could be effectively used during parts of a class lecture by having the instructor lead students in short experiments which directly illustrate to the student the topic or

concept of which the lecture was concerned. It is believed that this process would be especially effective during the introduction and discussion of series circuits, parallel circuits, and Ohm's Law relationships. This method has reference to what might be called "teacher directed experimentation."

Discussion

In a comprehensive study of an instructional method, effectiveness of teaching is usually given primary consideration. In this study, however, the writer attempted to place all the major facets of the 3-E program under investigation. A review of the 3-E text and the reference material used in teaching "Applied Electricity 140" at Kansas State College of Pittsburg indicated that although the two programs contain the same basic information, they did not stress the same topics nor did they have the same schedule for presenting fundamental concepts.

The differences in course content were available through direct observation of reference materials used in the two programs, however, such formulations were not possible when comparing the ability of the two programs to implant within students a knowledge and understanding of electricity-electronics fundamentals.

Since it was necessary to present the same basic information in the treatments, the standard course syllabus

for "Applied Electricity 140" at Kansas State College of Pittsburg was modified to offer the same basic concepts found in the first three chapters of the 3-E text and the ten related experiments.

The treatment given each group, although containing the same fundamentals of basic electricity, differed with respect to sub-topics emphasized, terminology, scheduling of activities methods of instruction, classroom teachers and their past teaching experience, equipment, reference materials, and included student assignment.

The results of the analysis of variance between means as presented in Tables II page 22 and IV page 23 and Table VII found in APPENDIX K indicate that according to pretest and posttest scores there was no significant difference in the effectiveness of treatments A and B.

As presented in APPENDIX K, Table V, all subjects made a positive gain in pretest-postest scores. It is interesting to note however, as can be seen in APPENDIX K, Table 8, that the number of students missing some questions was greater after treatment. With respect to Groups A and B separately, reference is made to the following questions:

Group A - 17, 22, 25, 33, 39, 41, 52, 58, 67, 71, 75, 79, 88.

Group B - 7, 28, 49, 63, 69, 88.

Although the questions, whose numbers are listed above, were actually missed more often after treatment, an analysis

of the selected responses to the question before and after treatment indicated that students were more likely to miss the question when only part of the knowledge needed to answer the question had been developed. It is believed by the writer that in this situation, the students lost the probability of chance in that they no longer guessed at the answers but rather selected some term, symbol, or concept of which they were cognizant. This is one of the possible explanations why ten students in Group A missed question #58 before the treatment and 13 missed it after treatment. An analysis of pretest and posttest responses to question #58 provided the following breakdown of responses:

Response	Times selected on pretest	Times selected on posttest
a	4	12
b	1	0
c	5	1
d	5	2

The total number of students selecting the correct response "d" was three less on the postest than on the pretest. Students receiving treatment A had been introduced to the symbols found in response "a" and "b". The selection of the correct response would have required either previous knowledge in electricity-electronics or the transfer of information learned during treatment. An analysis of student response

indicated that the students had not transfered knowledge but rather selected the response to which they were the most familiar. With reference to the questions missed more often after treatment, it appears that some students did increase their knowledge on the subject of the questions, but not to the extent needed to select the most correct response.

CHAPTER IV

SUMMARY AND CONCLUSION

Restatement of the Problem

The purpose of this study was to compare two methods of teaching basic electricity from data derived from test and observations. The two methods were: the 3-E program, A, developed by the McKnight and McKnight Publishing Company, and the "lecture-demonstration and project" method, B, used in the teaching of "Applied Electricity 140" at Kansas State College of Pittsburg.

The comparison of data from the two methods of instruction was computed by an analysis of variance between the means on posttest scores. Project construction activities and project reports were compared by the instructor involved in the study.

Experimental Design

In the present study two parallel groups were randomly selected and assigned treatments A and B. The random selection of groups was validated by computing an analysis of variance between means on pretest scores. As indicated in Table III, the groups were found to be not significantly different. Statistical data for a comparison of initial learning was derived from an analysis of variance on the mean of posttest scores.

The final experimental design was a modification of "Design 4" discussed in Campbell and Stanley (1963). The original design and its modification can be seen in Figures 1 and 2 (p. 21).

Population and Sampling

The population for the present study can be identified as:

> Students attending Kansas State College of Pittsburg during the spring semester of 1965 who were for the first time taking the course "applied Electricity 140", and who had been previously tested for intelligence and previous knowledge of basic electricity-electronics.

No significant differences were found between the subjects of the two treatment groups in terms of intelligence scores as measured by the Lorge-Thorndike Intelligence Test. No significant differences were found between subjects of the two groups in terms of previous knowledge of electricity-electronics as measured by the electricity-electronics test found in APPENDIX G.

The experimental groups were made up of thirty-two students giving a total N of sixteen for treatment group A, and for treatment group B.

A complete analysis of the subjects making up the final population may be seen in Table I, CHAPTER II.

The Learning Task

The learning task for the present study consisted of

the information contained in the first three chapters of the McKnight and McKnight 3-E program which are entitled as follows: a. Nature of Electricity b. Magnetism c. Electrical Measuring Instruments.

Treatment A was administered to group A by the writer using the 3-E program which utilized the "lecture-demonstration, project, and student experimentation method of instruction." Treatment was administered during class periods of "Applied Electricity 140" which met Monday through Friday from 8:30 a.m. to 9:30 a.m. The different instructional activities were scheduled according to the treatment outline presented in APPENDIX C.

Group B received treatment normally experienced by students enrolled in the class "Applied Electricity 140" at Kansas State College of Pittsburg. So that both groups would receive the same information the treatment outline used with group B was a modification of the normal course syllabus. The modified outline may be seen in APPENDIX D and the original syllabus in APPENDIX E.

Subjects in both groups took part in project construction activities, however, group A did not begin such activities until the information in CHAPTERS I and II of the 3-E text had been presented. A complete description of treatments A and B is presented in CHAPTER II.

Evaluation Instruments

The Lorge-Thorndike Intelligence Test and an electricity-electronics test were used to obtain data needed to check the validity of the random selection of groups. The electricity-electronics test was again used as a posttest to obtain measures of initial learning.

The electricity-electronics test contained ninety-two best answer multiple choice questions. A preliminary form of the test was given to an advanced electricity-electronics class at Kansas State College of Pittsburg who reported ambiguous and improperly constructed questions. The terminology used and questions asked were related to the information presented in both treatments. The electricity-electronics test may be seen in APPENDIX G.

Results

The following results were obtained on the basis of the data provided from an analysis of variance between means on scores of initial learning, and from a comparative evaluation of students project construction activities and project reports.

1. Subjects in groups A and B did not significantly differ in initial learning.
2. Subjects in group A and B did not differ in quality of project construction although there was indication

that group B placed more emphasis on meter accuracy.

3. Projects reports did not differ with respect to the criteria listed in the discussion of hypothesis 3, CHAPTER III.

Limitations

Any generalizations from the findings and observations of this study should be attempted only with the awareness that inherent limitations existed in the experimental procedure used in the present study.

1. The study was conducted using only three of the twelve chapters presented in the 3-E program.
2. It was necessary to reschedule the patterns of presenting "Applied Electricity 140" at Kansas State College of Pittsburg.
3. The present 3-E program is designed to provide a broad introduction to the subject of electricity-electronics. In comparison, the course "Applied Electricity 140" is designed to present a more technical and applicable introduction to the field of electricity-electronics.
4. The evaluation instrument used to obtain measures of initial learning was developed by an inexperienced teacher. The test was desgined to obtain measures of previous knowledge which reduced the validity of the instrument to obtain measures of initial learning.

5. With two instructors, it was impossible to control equally the information presented in treatments.
6. The final number of subjects used in the study was far below optimum quantity.
7. Observations were made by the instructors involved in the study and, although an attempt was made to formulate judgements in a professional manner the influence of human elements must be considered.
8. The present study was unable to compare the learning of group A and B in the following areas.
    1. Proficiency in the operation and use of electricity-electronics instruments and tools.
    2. The students personal development of attitudes concerning safety, industrial organization, and individual responsibility toward the welfare of himself and his fellow students.

Conclusions

The writer wishes to emphasize the fact that all conclusions are based on the population, treatments, test, and conditions of the study.

1. Treatment A and treatment B appear to be equally effective in terms of initial learning.
2. Treatment A and treatment B appear to be equally effective in teaching project construction activities although as compared to group B, subjects in group A

were inferior in their understanding and operation of electronics equipment.

3. The 3-E program helps compensate for an instructors lack of experienee by providing the student with equipment and materials needed for self-instruction.

Recommendations for Further Research

The present study has investigated under limited conditions only a segment of the 3-E program, which, is also only one of several "electricity-electronic package programs." With this point in mind, and from the results of the present study, the following recommendations for further study are made.

1. A study similar to the present one concerning the question: "Should the presentation of theory preceed or follow student experimentation and construction."
2. A similar study could possibly obtain more valid information if only one instructor were involved, and the entire 3-E program was presented for comparison.
3. A similar study could obtain information of greater meaning if a non-technical industrial arts program could be compared to the 3-E program.
4. Further studies would obtain much more accurate information by using a standardized test to obtain measures of pretest knowledge and measures of initial learning.

5. A study investigating the advantages and disadvantages of project construction in a basic electricity-electronics course with reference to learned related information, developed mental skills, and developed motor skills.

6. A study which compares two methods of instruction; one using the lecture-demonstration and project method, and the other using the lecture-demonstration and experimentation methods. Comparison would be made with reference to total information learned, mental skills developed, motor skills developed, and the development of industrial citizenship.

Implications of Industrial Arts Education

In considering the following implications for education it is important that the reader keep in mind the previously stated limitations of the present study.

From observations and experiences obtained in the present study, it appears to the writer that the "package-program" method of instruction is quite adaptable to the instruction of basic electricity-electronics and other industrial arts subjects as well. Reference is made to the introductory courses such as "basic wood," "basic electricity-electronics," "introduction to machine tool processes," etc. As the informational content of these subjects expand, it will ultimately become necessary to increase the amount of material presented in these introductory Industrial Arts courses.

It appears that the utilization of a "package-program" in appropriate courses would have the following contributions:

1. Instructors with little teaching experience would be aided in developing a course of study and course outline.
2. Instructors with many years of experience could use a "package-program" to assist them in offering new areas of instruction in which they were not trained.
3. A "package-program" usually contains a high percentage of the equipment needed to offer the course of which it is concerned. Thus it would be possible to offer courses which in the past have been deleted from the industrial arts curriculum due to the need of costly equipment.
4. The "package-program" provides the gifted and advanced student the opportunity of progressing at their own pace. Experimentation can be enriched and outside research can easily be encouraged.
5. Instruction by the "package-program" method does not utilize project construction activities to the extent commonly experienced by Industrial Arts students in the past. Students would therefore be permitted to develop a perceptive overview of an American industry such as electricity-electronics without being subjected to the manipulative motor activities found therin. Greater emphasis could then be placed on mental skills and

concepts of possibly greater asset to the students.

In conclusion, it is the writers impression that a "package-Program" will not provide in itself an instructional media desirable for all situations. The instructor in many cases will need to adapt the "package-program" method of instruction to the needs, objectives, students, and possible existing weaknesses of the course or program concerned.

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APPENDIXES

APPENDIX A

COURSE OUTLINE FOR TREATMENTS A AND B

COURSE OUTLINE FOR TREATMENTS A AND B

I. Nature of Electricity

1. Electron Theory
2. Conductors and Insulators
3. Electrical Units and Circuits
4. Generation of Electricity

II. Magnetism

1. Types of Magnets
2. Laws and Theory of Magnetism
3. Electromagnetism
4. Applications of Magnetism

III. Primary Electrical Measuring Devices

1. Meter Movement Devices
2. Ammeters
3. Voltmeters (AC and DC)
4. Ohmmeters (series and shunt)
5. Electronic Measuring Devices

APPENDIX B

3-E WORKBOOK INCLUDING EXPERIMENTS ONE-TEN

energy,

ELECTRICITY AND ELECTRONICS

For Course One of Three Courses in Electricity and Electronics

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Bloomington, Illinois

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Dedicated to you, the student — may you find the subject as interesting and exciting as it has always been to the authors.

Foreword

This manual has been written to aid beginners in their study of electricity. It contains experiments — learning situations — in which students investigate certain fundamental properties of basic electrical circuits.

The thirty-six *Experiments* in this manual are designed and organized in the proper order to be used with the material in the textbook, *Energy, Electricity, and Electronics.* Thirty-six *Additional Experiments* are outlined which may be included in the course of study, and thirty-six *Further Investigations* are suggested. This provides a total of 108 student activities which are keyed to the textbook.

Each of the basic *Experiments* contains:

1. A statement of the purpose of the experiment.
2. A brief summary of the material in the textbook covering the theory which is being demonstrated or applied in the experiment.
3. Directions for performing the experiment.
4. A pictorial layout and a schematic diagram.
5. Blanks for you to use to record your observations, with each observation leading to a logical conclusion concerning the basic electrical fundamentals under discussion.
6. A summary presenting several questions which you will answer concerning the material in the experiment.

The *Additional Experiments* contain only a schematic diagram of the circuit to be used in the experiment with suggested observations that you are to make. The *Further Investigations* suggest activities which are closely associated with the material in the text.

Problems have been included for several of the chapters where problem solving is necessary for a thorough knowledge of the subject covered in the textbook. The problems have been chosen to illustrate key points in these chapters. While each problem requires a certain amount of mathematics, the mathematical principles have been kept simple and within the scope of the average high school student.

The introductory chapter contains general instructions in the methods you will use in your experimentation and specific details on the equipment to be used.

This manual has been written to implement a philosophy for the teaching of electricity-electronics. It is the feeling of the authors that any course in electricity-electronics should be so organized that one-third of the time is spent in lessons, class discussions and teacher demonstrations; one-third should be devoted to project construction; and one-third should be spent in experimentation. These three functions of a course in electricity-electronics are represented by the textbook, the *Applied Activities* book, and this *Laboratory Manual.*

We hope that this manual will serve as an appetizer to those who are really interested in going further into the study of electronics.

Acknowledgments

Few books are ever the result of the efforts of only one person — indeed, the time and efforts of many persons have made this manual possible. The authors wish to express their deep appreciation to all those whose work is represented in this manual.

To Mr. Clarence W. Jones for his assistance in the construction of components for the pilot model of the equipment used in the performance of the experiments.

To Mr. Walter Lapp for his assistance in the preparation of the many diagrams and drawings which are used in the experiments.

To Mr. Curtis M. Brooks for his assistance in the preparation of the manuscript.

The Electronic Instrument Company of Long Island City, New York, graciously furnished the photograph and diagram of their model 526A multimeter and information on this instrument which has contributed to the educational value of this manual. Their contribution is welcomed and deeply appreciated.

Excellent photography was provided by Tri-Graphics, Inc., Buffalo, New York.

The Spaulding Fibre Co., Tonawanda, New York, provided circuit board materials for experimental development.

A word of thanks is also due to Mr. J. LeRoy Frazier, a member of the industrial arts staff of Old Dominion College, for his constructive help and valuable suggestions for the content of this manual.

Rex Miller
Fred W. Culpepper, Jr.

Contents

Introduction

Why Experiment?

All great discoveries in electricity-electronics have been preceded by a great deal of experimentation and observation. Sometimes the purpose has been simply to find out what happens when certain conditions exist. At other times the reverse has been true — the intention was to find out under what conditions a certain reaction or phenomenon would occur. This does not mean that experimentation is a haphazard affair with a lot of playing around. Experimentation is serious business!

Experiments are also used to prove that what is known in theory can be observed when the circuit or device being studied is caused to function as suggested by the theory. This is the main purpose of the experiments in this manual. Each experiment is used to *prove the theory* described in the textbook. A significant approach to teaching is that a student *learns by doing*. By performing each experiment, you have the opportunity to see the theory put into action. These experiments will make the material in the textbook more clear and help you to remember it.

Your Textbook and This Manual

This laboratory manual has been designed to help you in your job of learning about electricity-electronics. Compare the Table of Contents of this manual with the Table of Contents of the textbook *Energy, Electricity and Electronics*. You will find that they follow the same basic organization. Each chapter has the same heading. This manual has been written to be used with the textbook.

Chapter I of the textbook discusses the nature of electricity: the complete circuit, the flow of current, the generation of electricity, resistance, and Ohm's Law. In this manual, Chapter I has experiments on circuits and conductors, the generation of electricity, Ohm's Law, and resistance in series and parallel circuits. You can see that the two books are intended to be used together to help you learn the material quickly and easily.

The *Applied Activities* book is the third part of your program and it is organized in the same fashion. Its first chapter features projects which use the complete circuit and resistance.

How Will You Use This Manual?

The thirty-six experiments in this manual are all directly related to the material in the textbook. You should, if time permits, perform all thirty-six of these experiments.

Purpose of the Experiment

In each experiment precise instructions guide you in arranging the equipment and making observations. Let us examine the organization of a typical experiment. First, at the beginning there is a statement of the *purpose* for which the experiment is being performed. This is a very critical statement, and sets the theme for the entire experiment. Don't just glance at it, read the purpose carefully. It tells you why you are performing the experiment.

Summary of the Text

The next part of the experiment is a *summary of the text material* with a reference to those pages in the textbook which discuss the theory covered in the experiment. Also, this summary establishes the theme of the experiment and explains further the theory and the reason for performing this particular experiment. Read this section carefully. It will help you understand what is to follow.

Equipment Required

The third item in each experiment is a list of *equipment* necessary. When you are ready to perform the experiment you should obtain the required equipment from its proper storage space. Only when all of the equipment has been assembled at your work station are you ready to begin the experiment.

Procedure

The instructions for performing the experiment are found under the next heading, *the procedure*. You will notice several things about the procedure for each experiment. First, the instructions have been written very carefully. Second, when you are to turn on the power supply, the instructions *have been italicized.* Third, when you are to turn off the power supply, the instructions *again have been italicized.*

For each circuit to be constructed in the experiment, you have both a schematic diagram and a pictorial drawing. Try to construct your experiments *from the diagram,* not from the pictorial drawing.

Should you use only the pictorial drawing and put a wire or connector from point *A* to point *B*, you will not be getting the full benefit of the experiment. The pictorial drawings have only been included so that you might double check your construction of a circuit to be certain that it is properly assembled.

In the procedure there are a number of *questions* to be answered. Answer them carefully. In each instance, try to determine *why* that question has been asked. In writing the experiment, each observation was put in for a very definite purpose. Do not overlook any of the questions that are to be answered.

The last step of every experiment is to disconnect the circuits and return all equipment and material to their proper storage places. You must do your part to keep your electricity-electronics laboratory well organized, neat, and orderly.

The Summary

The *summary* of each experiment asks two or more questions about your observations as you performed the experiment. Answer these questions with care. They are the most important part of the entire experiment.

Making Observations and Recording Results

In the experiments you will often be asked to observe whether a light is *on* or *off*, whether it is *bright* or *dim*, or to read a meter and record precisely the meter reading. Be careful in making these observations. Be sure that these records are as accurate as you are capable of making them. Only *careful* observation and *accuracy* in recording the results will guarantee success in a program of experimentation. Be sure that you put down what is required in recording the results.

Accuracy cannot be stressed too strongly. Indeed, in some experiments a lack of exactness in recording your observations will result in incorrect answers to the problem in the experiment. Be as accurate as you can; be as neat as you can in recording your results; and be as careful as you can in making your observations.

Additional Experiments

There are thirty-six basic *Experiments.* Thirty-six *Additional Experiments* have also been included to give you an opportunity for further experience in experimentation. These Additional Experiments have been carefully chosen. Some of those included are typical "tricks" that can be done in electricity labs. For example, the "jumping ring" has been used for years to illustrate effects of transformer action.

In order to be able to perform these Additional Experiments, you must first perform all of the basic experiments for the chapter. Then, if time permits, your instructor will give you permission to perform the Additional Experiments for that chapter.

The Additional Experiments do not have a pictorial drawing. You are expected to work solely from a schematic diagram of the circuit. Since this is advanced work, the Additional Experiments do not have a procedure that is worked out in detail, but only suggest observations that you should make. You should

study the experiment to see *why* these observations are suggested. Your instructor will outline the method to use when you make a report on the Additional Experiments that you have performed.

Be exceptionally careful in performing the Additional Experiments. Do not go beyond the scope of the material outlined without the *permission of your instructor.*

Further Investigations

In addition to the *Additional Experiments,* thirty-six *Further Investigations* have been included in this manual for those students whose time and ability permit them to investigate some electrical circuits without having a schematic to guide them. In these *Further Investigations,* you must draw the circuit diagram and have it approved by your instructor before you connect the circuit and begin the experiment. Many of the Further Investigations are activities that could be reported to the class, or used as an exhibit for an open house. Your instructor will announce in class his plan for allowing you to perform the Further Investigations.

Student Organization

These experiments have been written in such a way that they may be performed by one student working alone, or by two students who serve as laboratory partners. If your instructor assigns two students to each work station, you will perform the experiment with your partner. When you do this, try to share the responsibility for performing the experiment. Try not to form the habit of having the same person set up the circuit every time, or one make all the observations with the other copying his work. Share the responsibility for the performance of an experiment, so that both will profit equally from this experience.

Your Equipment and Its Use

The following equipment and material are necessary for the performance of the experiments in this manual:

1. Circuit Board 1
2. Circuit Board 2
3. Circuit Board 3
4. Circuit Board 4
5. Circuit Board 5
6. Power Supply
7. Multimeter – EICO Model 526A with Test Prods (or its equivalent)
8. Motor Generator Unit (Circuit Board 4)
9. Field Coil for Above
10. 1 Jar of Iron Filings
11. 10 ft. Common String
12. 1 Pair Bar Magnets
13. 100 Iron Washers, ¼″
14. 1 Electric Cell Unit, Composed of Glass Tumbler and Cell Element Holder
15. 2 Lead Strips ¾″ x 5″
16. 1 Iron Strip ¾″ x 5″
17. 6 Aluminum Strips ¾″ x 5″
18. 1 Tin Strip ¾″ x 5″
19. 1 Zinc Strip ¾″ x 5″
20. 1 Nickel Strip ¾″ x 5″
21. 1 Copper Strip ¾″ x 5″
22. 1 Carbon Strip ¾″ x 5″ x ⅛″
23. 2 Wood Dowels ¼″ x 5″
24. 1 Carbon Rod ¼″ x 5″
25. 1 Plastic Rod ¼″ x 5″
26. 1 Tool Steel Rod ¼″ x 5″
27. 1 Friction Rod 10″ x ½″
28. 2 Pith Balls on Thread
29. 1 Jar Ammonium Chloride Solution, Concentrated
30. 1 Wool Cloth 12″ x 12″
31. 1 Jar Sulphuric Acid Solution, 10%
32. 1 Jar Copper Sulphate Solution, Concentrated
33. 1 Jar Salt Water Solution, Concentrated
34. 2 Candles
35. 1 Headphone, Magnetic
36. 1 Telegraph Key with Connecting Leads
37. 1 Two-Watt Neon Lamp
38. 1 60-Watt Incandescent Lamp
39. 1 25-Watt Incandescent Lamp
40. 1 15-Watt Incandescent Lamp
41. 2 "A" coils, 300 Turns #22 Wire
42. 2 "B" Coils, 900 Turns #28 Wire
43. 1 "C" Coil, 125 Turns #18 Wire
44. 1 Laminated Bar, ¾″, for Circuit Board 3
45. 1 Aluminum Washer
46. 15 feet #24 Nichrome Wire
47. 15 feet #24 Iron Wire

48. 15 feet #24 Bare Copper Wire
49. 15 feet 1 Amp. Fuse Wire
50. 1 set Test Prods for Circuit Board 2
51. 1 Line Cord
52. 1 Pair Meter Leads for Multimeter
53. 1 Pair Connectors for Circuit Boards
54. 1 Pair Alligator Clip Leads
56. 1 Pair Banana Plug Taps
57. 7 Snap Leads, 11″
58. 15 Snap Leads, 6½″
59. 1 Empty ¾″ Coil Bobbin
60. 1 Asbestos Cloth Pad

This equipment and most material is available as a unit from the McKnight & McKnight Publishing Company, Bloomington, Ill. 61702.

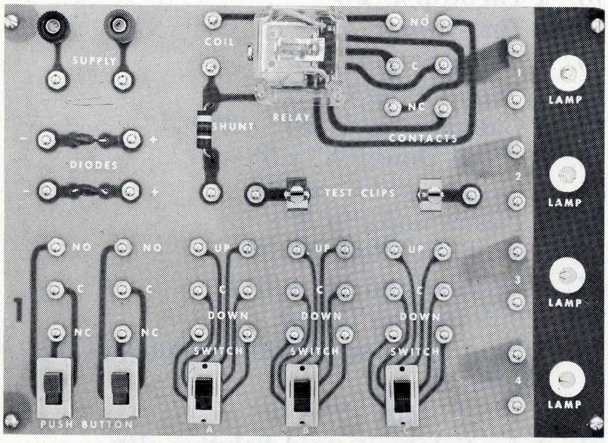


Fig. 1. Top View of Circuit Board 1

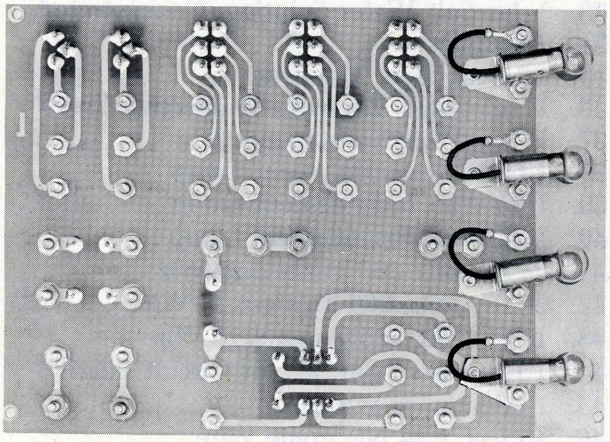


Fig. 2. Bottom View of Circuit Board 1

The Circuit Boards

Circuit Board 1

Circuit Board 1 is primarily designed for low-voltage experimental circuits. Fig. 1 is the top view of the circuit board and Fig. 2 is the bottom view of the circuit board.

A double-pole, double-throw relay which has a coil resistance of 115 ohms is mounted on the board. It is designed for operation on six volts DC. The two diodes in the upper left corner of the circuit board are rated at 1 ampere with a 400-volt peak inverse rating. Four 6-volt lamps are below the surface at the right. At the lower left, two momentary-contact slide switches (push buttons) are single-pole, single throw. The other three switches are double-pole, double-throw slide switches.

Circuit Board 2

Circuit Board 2 is designed for direct current meter circuits. The top of the board is shown in Fig. 3 and the bottom of the board is shown in Fig. 4. Mounted on the right side of the board are four cell holders, for standard pen light cells. The zero-adjust potentiometer is located below the photo cell and the cell holders. It is a 1500-ohm, two-watt, wire-wound potentiometer. The meter in the upper left corner is a zero-centered, 1-0-1 milliampere meter. The resistors located on the bottom left side of the circuit board are used in the construction of Ohm's Law circuits and are

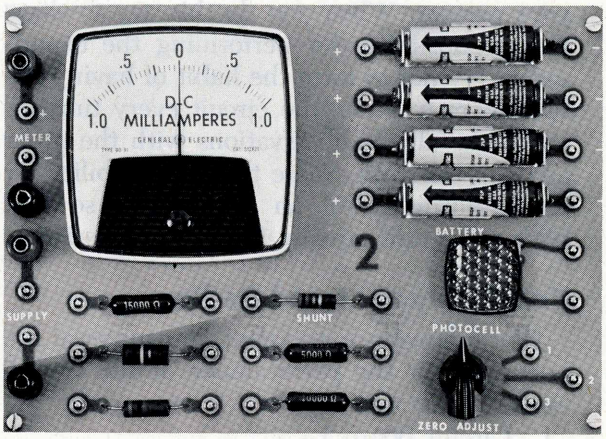


Fig. 3. Top View of Circuit Board 2

also used in meter circuits. Most resistors have a tolerance of 5%. A photo cell is included.

Circuit Board 3

Circuit Board 3 has been designed for alternating current circuits which use capacity and inductance. The top of the board is shown in Fig. 5. The bottom of the board is shown in Fig. 6. The inductor frame is made from laminations and is so constructed that any one of the coils can fit on the frame as shown in Fig. 7.

The lamp socket in the front of the circuit board is a standard lamp socket designed to hold a neon lamp and various incandescent lamps required in the experiments. In the lower left corner of the circuit board, a simple rectifier circuit has been constructed. It will produce an output of 1 ampere at a variable voltage output depending upon the amount of voltage supplied to the rectifier unit. The maximum input to the rectifier is 120 volts AC.

The capacitors on the left side of the board are all rated at 400 working volts at 10% tolerance. At the top left of the board are mounted a 5000-ohm resistor and a 1-megohm resistor which will be used in the experiments. The switch at the bottom of the board is a single-pole, single-throw switch which is used in some experiments.

CAUTION: ***This circuit board will have 120 volts on its terminals in some experiments. Connect the snap leads firmly so that one will not pop off during an experiment and cause a short circuit. Do not make connections or touch snap leads when the power is on.***

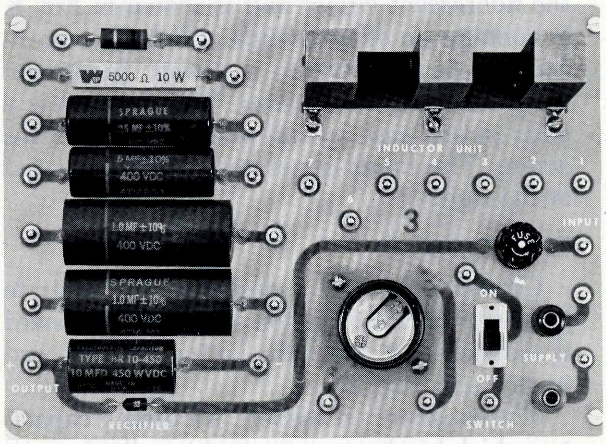


Fig. 5. Top View of Circuit Board 3

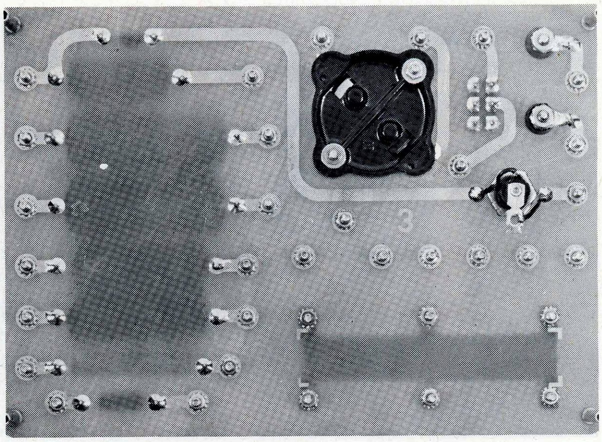


Fig. 6. Bottom View of Circuit Board 3

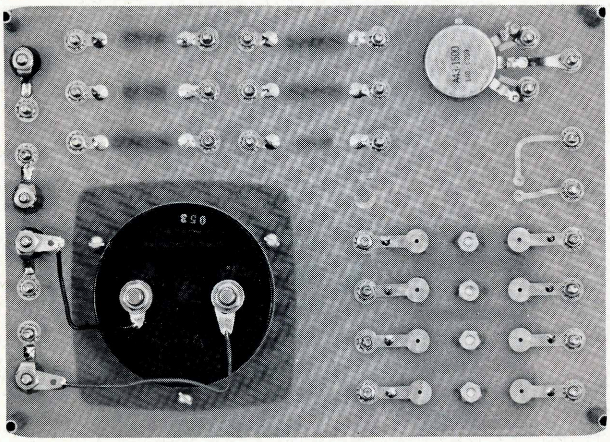


Fig. 4. Bottom View of Circuit Board 2

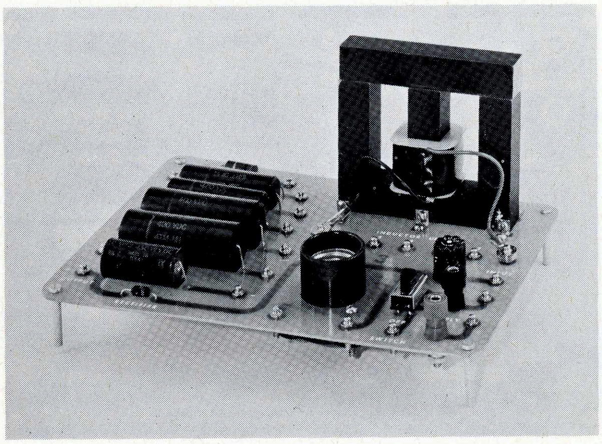


Fig. 7. Close-Up of Inductor Unit

Circuit Board 4

Circuit Board 4 is designed to demonstrate the fluorescent circuit and is shown in Fig. 8. It contains an off-on switch, a ballast, a push-button starting switch, a 4-watt fluorescent lamp and a special starter. The starter has a clear plastic case so that you can observe the action. The motor-generator unit is mounted at the right.

Circuit Board 5

Circuit Board 5 is designed to illustrate transistor circuits. The top surface of the board is shown in Fig. 9 and the bottom of the board is shown in Fig. 10.

The capacitor on the left is a tuning capacitor which has been connected to a flat transistor antenna coil. This combination is resonant at that band of frequencies used by AM broadcasting stations. The detector is a crystal-diode type; the volume control has been connected through the circuit board to the input transistor. All circuits on this board use resistor-capacitor networks which have been pre-wired. This eliminates the necessity of learning many component values for each circuit used.

Additional Equipment

The *cell unit* shown in Fig. 11 makes it possible to connect various types of cells used in the study of electricity. It is composed of an element holder and a glass tumbler.

The *motor-generator unit* shown in Fig. 12 is used to study simple AC and DC generators

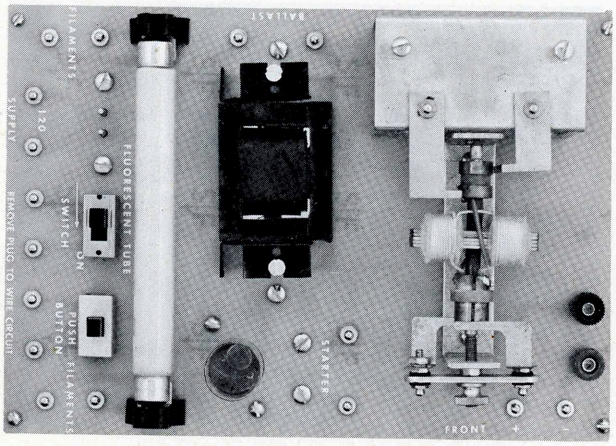


Fig. 8. Top View of Circuit Board 4

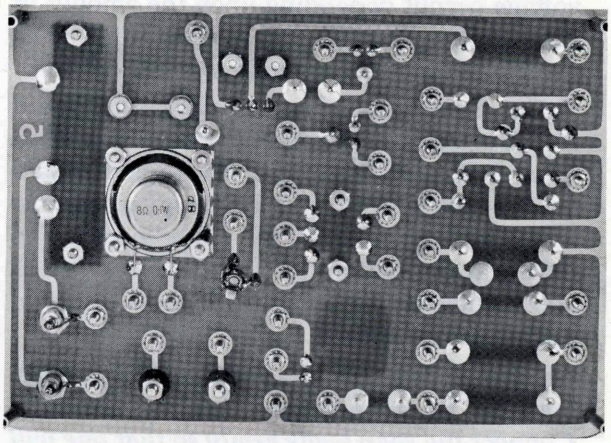


Fig. 10. Bottom View of Circuit Board 5

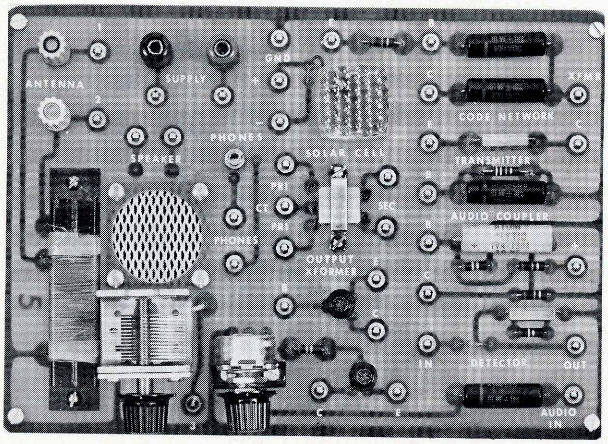


Fig. 9. Top View of Circuit Board 5

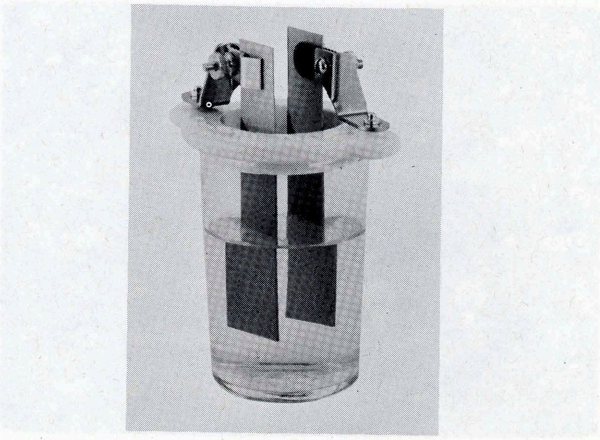


Fig. 11. Assembled Cell Unit

and DC motors. It may be used with either a field coil, shown in Fig. 13, or with bar magnets which can be clamped in the brackets provided on the unit.

Any type of *power supply* that utilizes an *isolation transformer* and has an output of 0 to 120 volts AC (rated at 2 amps or more) and an output of 0 to 15 volts DC and AC (rated at 5 amps or more) will be satisfactory with this equipment. CAUTION: ***The power supply must have an isolation transformer.*** Many manufacturers supply such power supplies to schools. In operating a power supply, always turn the voltage control knob (usually a variac) to the minimum voltage output position before connecting the power supply to the circuit board. Then connect the circuit board to the power supply. On DC experiments, the positive terminal of the circuit board connects to the positive terminal of the power supply, and the negative terminal of the circuit board connects to the negative terminal of the power supply. On AC circuits, polarity is not critical.

A power supply designed for use with these experiments can be purchased with the circuit boards, Fig. 14.

Making Connections

The connections on the circuit board are snap connectors which must be placed snugly in position to function correctly. The snap connector is connected to its stud by applying an even pressure of the fingers to the top of the snap, as shown in Fig. 15. After making a connection always test by pulling gently to be certain that the snap connector is connected as it should be. To remove a snap connector, place the thumb of the right hand on the forward edge of the connector with the forefinger and the middle finger of the right hand under the wire going to the connector. A wedging

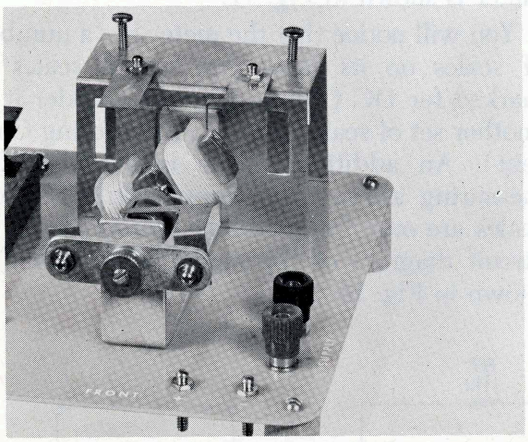


Fig. 12. Motor-Generator Unit without Magnets and Field Coil

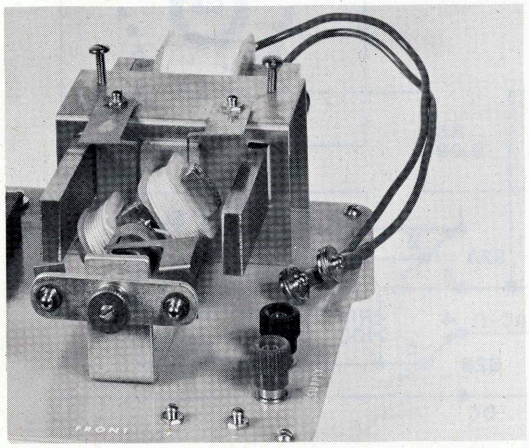


Fig. 13. Motor-Generator Unit Assembled

Fig. 14. Power Supply Unit

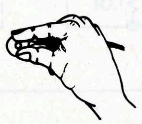


Fig. 15. Pressing a Snap Connector in Place

Fig. 16. Removing a Snap Connector

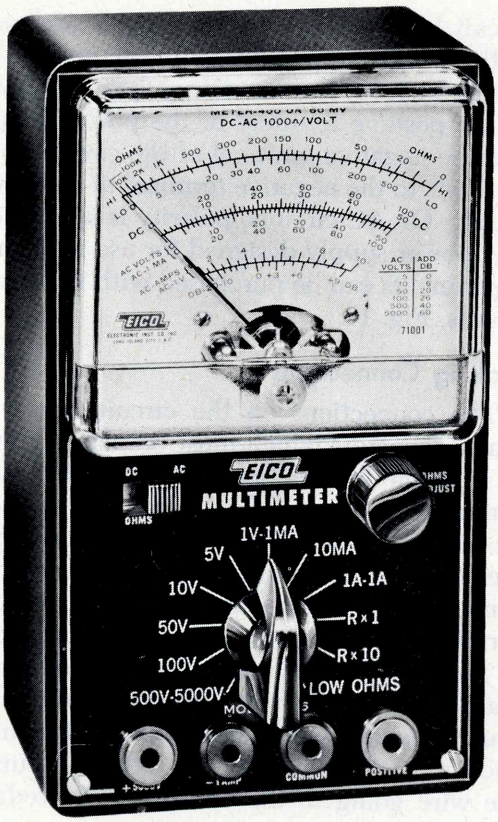


Fig. 17. Eico Multimeter

action will immediately "pop" the snap connector off of the stud. This action is shown in Fig. 16.

Do not try to pry off a snap connector or try to remove a snap connector by a vertical pressure. This will only result in damaging the circuit board since these connectors will hold tight unless removed in the proper manner.

Connections between various parts of the circuit and supplementary equipment are made with other appropriate connectors.

How to Use the Multimeter

The Eico model 526A multimeter is a 1000 ohm-per-volt 31-range meter and is recommended for use with this equipment. The meter is shown in Fig. 17.

You will notice that the meter has a number of scales on its face. One set of scales is marked for DC (Direct Current); under it is another set of scales for AC (Alternating Current). An additional scale is available for measuring alternating current while the top scales are only for resistance measurement. A circuit diagram of the model 526A meter is shown in Fig. 18.

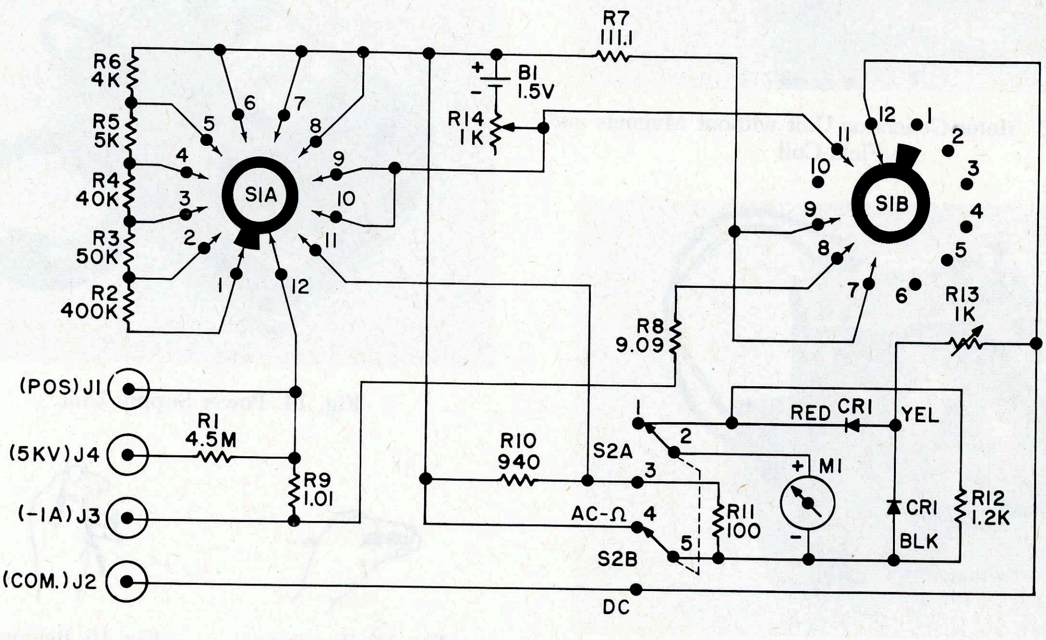


Fig. 18. Diagram of Eico Multimeter

The instrument provides for voltage measurements of both AC and DC from .1 volt to 5000 volts. It also provides for direct current and alternating current readings from 0.1 milliampere to 1 ampere. The voltage ranges for the meter, AC or DC, are 0-1, 0-5, 0-50, 0-100, 0-500, 0-5000 volts. Currents, AC or DC, may be read from 0-1, 0-10, 0-100 milliamperes and also 0 to 1 ampere. The resistance ranges are 150-ohm, center scale on the R x 1; 1500-ohm, center scale on the R x 10; and 55-ohms, center scale reading on the low ohms.

DC Voltage Measurement

To measure DC voltages with the multimeter, set the DC-AC switch to the DC position. Set the range switch to the voltage range which you have been instructed to use in your experiment. In making a measurement, should the needle deflect in the wrong direction, simply reverse the leads. DC voltages are read on the black scales which are marked DC. When using the 50- and 100-volt ranges, the meter scale is read directly. When reading voltages in the lower ranges, the meter readings in the five-volt and ten-volt ranges must be *divided by 10* – and *divided by 100* for the 0-1 volt range. In reading 500 volts on the meter, the 0-50 scale reading would have to be *multiplied by 10.*

AC Voltage Measurement

To read AC volts on the multimeter, set the DC-AC switch to the *AC* position. Set the range switch to that voltage range which you are instructed to use in the experiment. Read the 0-50 and 0-100 scales marked AC volts on all voltage ranges except the 1-volt range and the 10-volt and 500-volt ranges. For these voltages, the meter reading would have to be divided or multiplied the same as in DC. Be sure that in reading the scales that you read the *red scale for AC* and the *black scale for DC*.

DC Current Measurement

Set the DC-AC switch in the *DC* position. Set the range switch at the current you are about to measure or the range which you have been instructed to use in your experiment. Read the current on the black DC scale. When using the 0-1 milliampere range divide the 0-100 scale by 10; when measuring 0-100 milliamperes, read the 0-100 scale directly. To increase the reading to 1 ampere, remove the black plug from the common terminal and insert it instead into the jack marked "–1 amp". This reading is made with the selector switch at the .1 –1 amp position.

AC Current Measurement

To read AC current, set the DC-AC switch to the *AC* position. Read the red 0-10 scale marked AC amperes on all current ranges except the 0-1 milliampere range at which time you use the red scale normally used for reading voltages. When measuring 0-1 milliampere AC, divide the 0-100 scale by 100. In reading the 0-10 milliamperes, read the AC ampere scale directly. For the 0-100 milliampere range, multiply the 0-10 milliampere scale by 100. To read 0-1 ampere AC, move the black common connection from the common terminal to the "–1 amp" connection, read the AC 0-10 ampere scale, and divide the reading by 10.

Resistance Measurement

Set the DC-AC switch on the *DC* position. With the test prods shorted together on the R x 1 or R x 10 range, rotate the ohm adjust control until the meter pointer is exactly over zero on the black scale on the top of the meter which is marked *high ohms*. For adjustment on the low ohms range, do not short the meter prods together, but rather, place the selector switch in the low ohms position and rotate the zero ohm adjust knob until the pointer rests even with the right side of the scale for low ohms. Connect the test prods to the resistance being measured. On the R x 1 range use the top scale and read directly. For R x 10 use the top scale and multiply by 10. For low ohms read the lower black scale marked ohms. Be careful that no voltage is in the component whose resistance you are attempting to measure as such voltage will damage the meter.

Care of Equipment

Your school has invested a lot of money to provide a course in electricity and electronics for you. The equipment has been constructed to be as rugged as it possibly can be. Yet, accidents will occur, and equipment may be damaged.

Use the equipment with care. Do not connect a high voltage to some device which has been made to operate on a lower voltage. Do not subject the equipment to abuse.

Should you experience an accident, or have a piece of equipment break while you are using it, report this immediately to your instructor. Do not try to hide a piece of broken equipment. If you do neglect to report a piece of broken equipment and the instructor does not know about it, the next time you perform an experiment, you may be the one to receive a piece of inoperative equipment.

Be careful with the equipment, and report all accidents to your instructor.

Safety

In addition to being careful of the equipment, be careful of your own personal safety. *Electricity can be a shocking subject*. A shock to someone else can be very funny, but it is usually not very funny to the person who is being shocked!

Never work on a circuit board when the circuit board is energized (power supply on) unless specifically instructed to do so in the procedure. If you are instructed to work on the circuit while current is flowing in the circuit, be especially careful. Do not let yourself become a part of the circuit.

Should you have an accident – for example spill some acid or be badly shocked – report it immediately to your instructor. Do not cause someone else in your class to be shocked. This is not only foolish and childish, it is exceedingly *dangerous!* Be careful of your own safety and the safety of others in your class.

Now you are ready to experiment!

Experiment 1

Circuits and Conductors

Purposes

1. To investigate the properties and characteristics of the complete electrical circuit.
2. To investigate common substances to determine whether they are insulators or conductors.

Summary of the Text Material

Electricity is a flow of electrons along a conductor. For such a flow of electrons to exist, it is necessary that there be a *complete circuit*. To have such a circuit there must be (1) a source of electrical power, (2) a load to which the power is applied, (3) a path for electrons to pass from the source to the load, and (4) a return path for the electrons to pass from the load to the source. The path along which the electrons flow is called a *conductor*.

Typically, a conductor is a piece of metal in the form of a wire. Metals are excellent conductors of electricity, because they have a surplus of free electrons. These free electrons make possible the electron flow through a conductor.

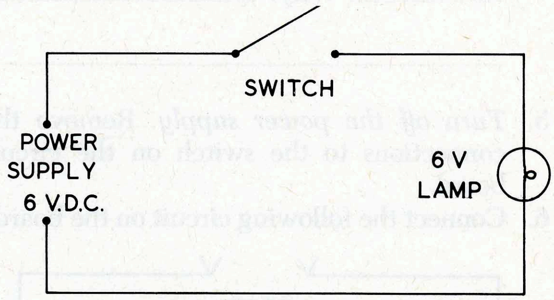
Generally speaking, all materials may be classified as either conductors of electricity, nonconductors of electricity, or partial (semi) conductors of electricity. In this experiment, you will first investigate the characteristics of a complete circuit. Then you will use a complete circuit to test various materials to determine whether they are conductors or insulators.

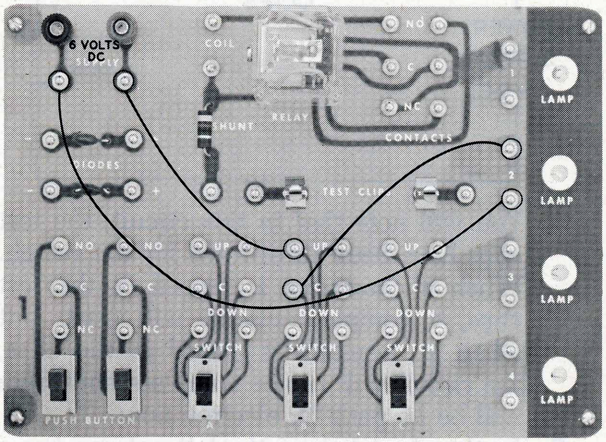
Equipment Required

1. Power Supply
2. Circuit Board 1
3. Iron Wire (3½″ long)
4. Bare Copper Wire (3½″ long)
5. Aluminum (5″ x ¾″) Strip
6. Carbon (5″ x ¾″) Strip
7. Plastic Rod (5″ x ¼″)
8. Wood Dowel (5″ x ¼″)
9. Paper (4″ x 1″)
10. String (4″ long)

Procedure

1. Connect the following circuit: *(Be sure the power supply is off.)*





2. With the switch on the circuit board in the *off* position (down), turn on the power supply and adjust the output to 6 volts DC.
3. Turn the switch on the circuit board *on*.

What happens to the light?..

....

Does this indicate that the circuit is now complete?.......................... Why?..............................

....

....

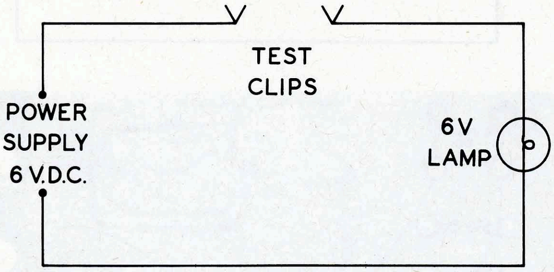
CAUTION: ***Always turn off the power supply before working on the circuit board.***

4. Remove the snap lead on one side of the lamp. Does the light continue to burn?

   .... Why? ....

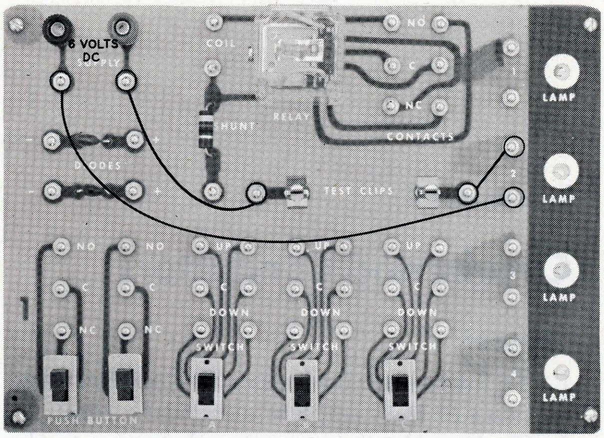
   ....

5. *Turn off the power supply.* Remove the connections to the switch on the circuit board.
6. Connect the following circuit on the board:



You will note that in this circuit, the test clips have been substituted for the switch. When a conductor is placed in the test clips, a complete circuit will exist, but when an insulator is placed in the clips, the circuit will not be complete and there will be no path for electron flow.

7. In the chart below, the left column has a number of materials listed which you are to place between the test clips. You will then record whether the light is *on* or *off* and from this conclude whether the ma-



terial is a conductor or an insulator. *Turn on the power supply* (with the same output as before; 6 volts DC) and proceed to test each material.

Material	Does the Lamp Light?	Conductor	Insulator
1. Iron Wire			
2. Copper Wire			
3. Aluminum Strip			
4. Carbon Strip			
5. Plastic Rod			
6. Wood Dowel			
7. Paper			
8. String			

8. *Turn off the power supply,* disconnect the circuit, and return all equipment and materials to their proper storage places.

Summary

1. What is necessary to have a complete circuit?

   ....

   ....

   ....

2. What causes some materials to be conductors while others are insulators?

....

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3. How is the circuit of Step 6 similar to the circuit of the Elementary Teaching Machine on page 14 of the *Applied Activities* book?

....

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Experiment 2

Generation of Electricity

Purpose

To investigate several representative methods of generating an emf.

Summary of the Text Material

The force which causes a movement of electrons through a conductor is called an *electromotive force* (emf). Voltage and emf are interchangeable terms and mean essentially the same thing. An emf can be generated in several different ways.

In this experiment, you will generate an emf by the use of *friction,* in which a hard rubber rod is rubbed with a piece of wool cloth to generate a static charge. You will observe the *chemical method* in which two dissimilar metals and an electrolyte generate an emf. Also, an emf will be generated by the use of *applied heat* in which the two dissimilar metals become a *thermocouple.*

Recently a new discovery, the *sun battery,* has gained wide attention as a method of generating an emf. Many of our space satellites use sun batteries as their power source. You will experiment with such a sun battery.

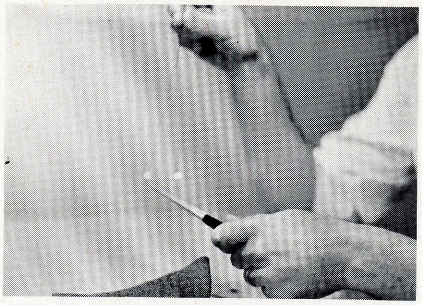
The most popular commercial method of generating an emf is by means of *magnetism,* in which a coil of wire is moved in a magnetic field. This is the basis for the operation of the commercial generator, an example of which would be the generator or alternator in the automobile.

Equipment Required

1. Friction Rod and Wool Cloth
2. Pith Balls on Threads
3. Zinc and Copper Bars
4. Salt Water Solution
5. Circuit Board 2
6. Bar Magnet
7. Coil *A*
8. Copper Wire
9. Iron Wire

Procedure

1. Straighten out the threads attached to the pith balls and place them on the bench so they can be picked up easily. The threads should be held at least six inches from the balls and the balls should be touching one another when suspended.
   Hold the friction rod in the left hand and the piece of wool cloth in the right hand. Rub the rod briskly with the wool cloth for several seconds.



2. Still holding the rod with the left hand, place the wool cloth on the bench. Pick up the pith balls, holding them suspended from the threads.
   Bring the charged friction rod close to the pith balls. What happens to the pith balls?

....

....

....

After the rod has touched the pith balls and is withdrawn, what happens to the pith balls?

....

....

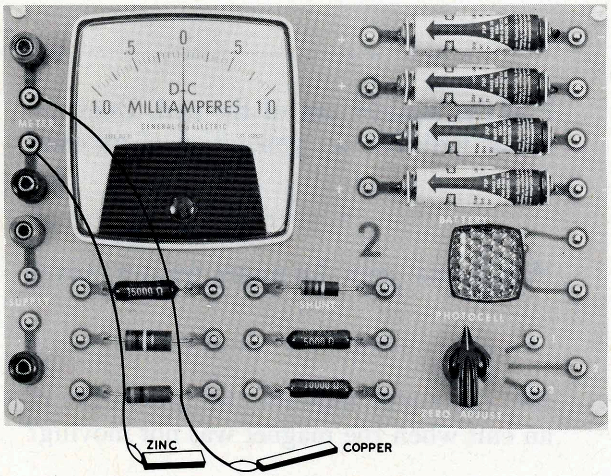
....

Why?..............................

....

....

3. Using alligator clip leads, connect the copper bar to the positive terminal of the meter movement of Circuit Board 2. Connect the zinc bar to the negative terminal of the meter movement.



Moisten a piece of paper towel (or other absorbent paper) with the salt water solution and place it between the copper and zinc bars. What indication is there of the generation of an emf?

....

....

....

....

4. Repeat Step 3 using a piece of paper moistened with saliva. What indication is there of the generation of an emf?

....

....

....

You may have experienced the sensation of pain when a piece of metal has touched a fresh filling in a tooth. In view of the findings in generating an emf with saliva, what is the probable cause of this pain?

....

....

....

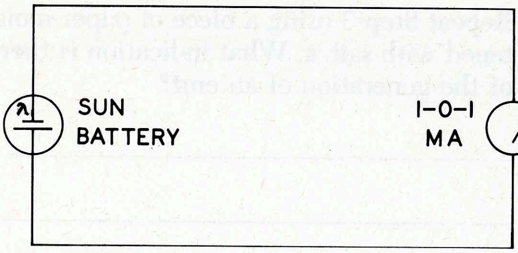
5. Cross the copper and iron wires about two inches from one end. Twist the wires together for the remainder of their lengths. In order to compress the length of the twisted section, wrap it around a pencil. Remove the pencil.
Connect the copper wire to the positive terminal of the meter movement and the iron wire to the negative terminal of the meter movement.
Light the candle and heat the twisted section of the wire. (Another source of heat can be used if preferred.)
Is there any evidence of the generation of an emf?

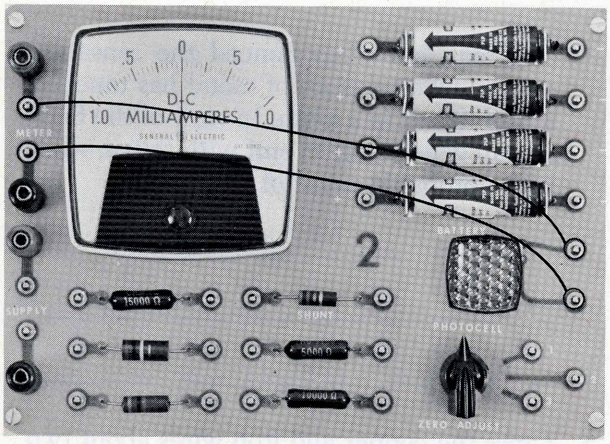
....

Is this method of generating an emf as efficient as the chemical method?..............................

....

6. A sun battery is mounted on Circuit Board 2. Connect the meter movement to the sun battery as shown on page 24.





Is there any indication of the generation of an emf?

....

Bring a strong source of light close to the sun battery. Does the meter deflection indicate more or less emf being generated?

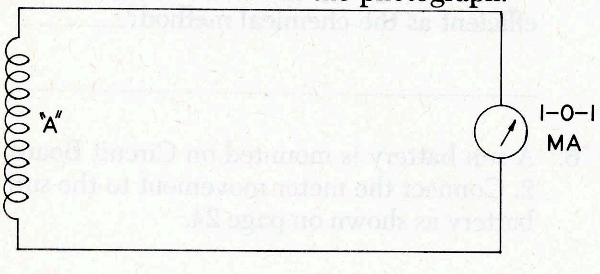
....

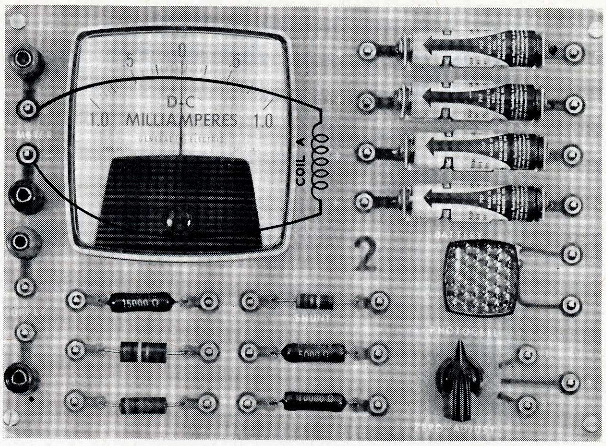
Why would this be true? ....

....

....

7. Connect the meter movement to one of the A coils as shown in the photograph.





8. Using one of the bar magnets, push the north pole of the magnet into the coil. Is there any indication of the generation of an emf?

....

Which way does the meter pointer move?

....

Pull the magnet out of the coil. Does the meter indicate any generation of an emf?

....

Which way does the meter pointer move?

....

Did the meter indicate the generation of an emf when the magnet was not moving?

.... Why? ....

....

....

....

....

9. Disconnect all circuits used, clean and return all equipment and materials to their proper storage places.

Summary

1. List the different methods of generating an emf as shown in this experiment and give a practical application for each method.

2. One method of generating an emf discussed in the textbook was omitted from this experiment. What is this method and what are some practical applications of this method?

Experiment 3

Ohm's Law

Purposes

1. To gain a familiarity with Ohm's Law in its many possible forms.
2. To demonstrate and prove the mathematical relationships of Ohm's Law in operating circuits.

Summary of the Text Material

Ohm's Law is one of the basic relationships of electricity. In fact, it might almost be said that Ohm's law is *the* basic relationship in electricity. Every serious student of electricity should have a very thorough understanding of the operation of Ohm's Law.

In this experiment you will construct circuits containing resistance, measure the voltage drop across the resistor and the current through it, and thus prove the relationships in Ohm's Law. The mathematical results in your experiments and the physical quality of resistance may not precisely match; that is, the voltage indicated by Ohm's Law may not be exactly the same as that read on the meter. These discrepancies can be caused by the *tolerance* of the resistance elements and by small errors in reading the meter. However, in most instances the experimental value and the mathematical value will be sufficiently close to achieve the desired results.

A student of electricity should accustom himself to thinking of values of circuit components as being within certain *tolerance levels* and not the exact value noted on the component. For example, in this experiment the resistors have a tolerance of plus or minus 5%. That means that if the marked value on the resistor is 1000 ohms, the actual acceptable value can be anywhere between 950 ohms and 1,050 ohms.

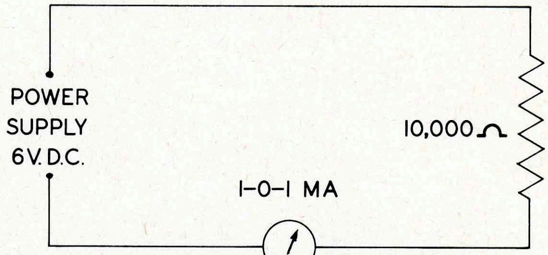
Another probable source of error in an experiment in electricity is introduced by the reading of the meter. To obtain the most accurate meter reading, try to get your eye directly in front of the needle. Close one eye. Reading a meter at an angle is a poor practice.

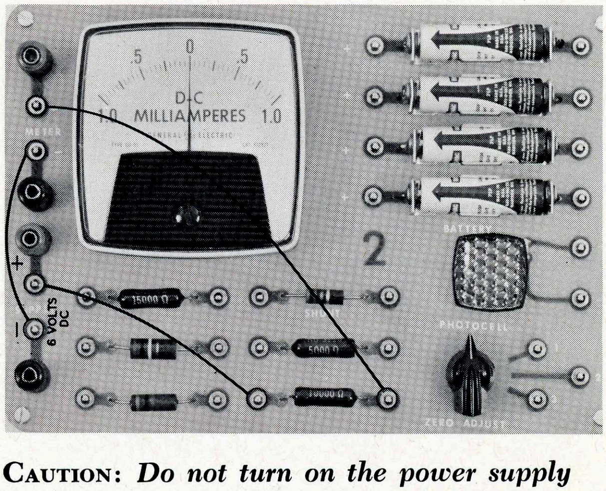
Equipment Required

1. Circuit Board 2
2. Power Supply

Procedure

1. Connect the following circuit:





Caution: ***Do not turn on the power supply until instructed to do so in the procedure for each experiment!***

2. Set the voltage control for the power supply at the minimum output, *turn on the power supply,* and slowly advance the voltage control to an output of 6 volts.
3. The circuit that you have just connected contains a single 10,000-ohm resistor connected to a source of 6 volts. By Ohm's Law, what is the current through the resistor supposed to be?

....

....

4. What current is flowing in the circuit as indicated by the reading of the milliammeter?

....

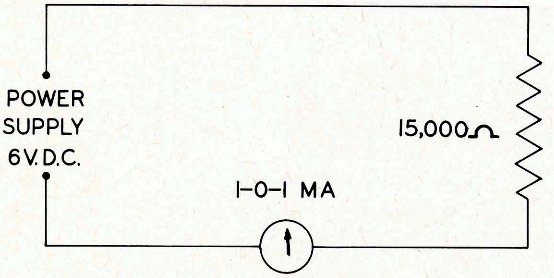
Is there a difference between this reading and the answer you obtained in Step 3?

.... If there is, what would account for the difference?..............................

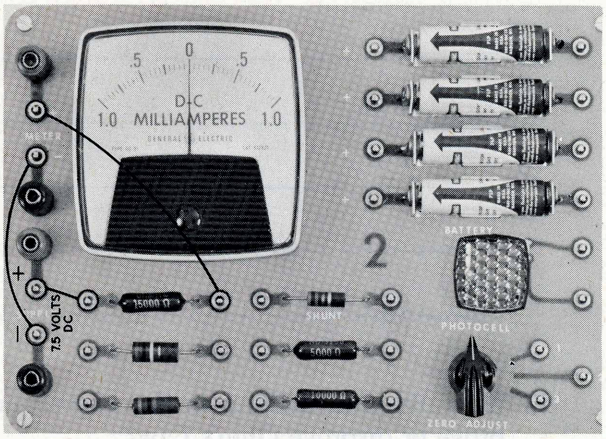
....

....

5. *Turn off the power supply.* Disconnect the circuit you have been using and connect the following circuit:



6. In this circuit, a 15,000-ohm resistor has been substituted for the 10,000-ohm resistor in the preceding circuit. *Turn on the power supply,* and adjust the voltage output to 7.5 volts. What is the current



through the resistor as determined by the reading of the milliammeter?

....

7. Reduce the voltage to 6 volts. What is the current through the resistor?

....

Turn off the power supply.

8. What happens to the current in a circuit when the voltage remains the same and the resistance of the circuit is increased?

....

....

9. What happens to the current in a circuit when the resistance remains the same and the source voltage is increased?

....

....

10. Disconnect all circuits used, and return all equipment to its proper storage place.

Summary

1. What does Ohm's Law state?

....

2. How did your findings in this experiment prove or disprove Ohm's Law?

Experiment 4

Resistance in Series and Parallel

Purposes

1. To become familiar with circuits with more than one resistor and to study the relationships that exist between the voltage, the current, and the effective resistance in such circuits.
2. To obtain evidence that will prove the mathematical relationships that exist in circuits containing more than one resistor.

Summary of the Text Material

Seldom is an electrical circuit encountered in which there is only one source of resistance. Generally speaking, electrical circuits will have several sources of resistance, arranged either in series, in parallel, or in any combination of series and parallel.

When two or more resistors are so connected that the current flowing through one is the same current as that flowing through another, the resistors are said to be connected in series. In such a circuit the voltage drops across each resistor are added to give the total voltage drop of the circuit. In computing the equivalent resistance of resistors connected in series, their individual resistances are added.

When two resistors are connected in such a way that the current flowing in the circuit is divided with part flowing through each resistor (uniting again after flowing through the resistors) the circuit is said to be a parallel resistance circuit. In such a circuit the voltage across one resistor is the same as the voltage across the other. The equivalent resistance of the circuit is, mathematically stated, the reciprocal of the sum of the reciprocals of the individual resistances. This sounds quite complicated when written out, but when expressed in a formula is quite easy to understand. The formula for equivalent resistance of a parallel resistor network is as follows:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots\cdot$$

R_T = Equivalent Resistance

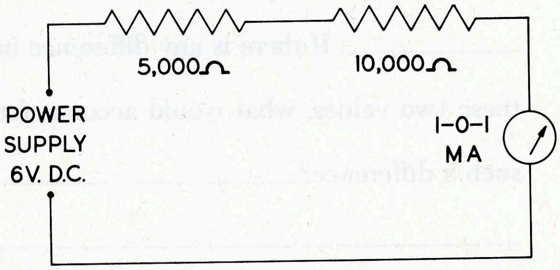
In this experiment you will connect series and parallel resistance circuits and study the voltage relationships, the current relationships, and the equivalent resistances of the circuits.

Equipment Required

1. Circuit Board 2
2. Power Supply
3. Multimeter

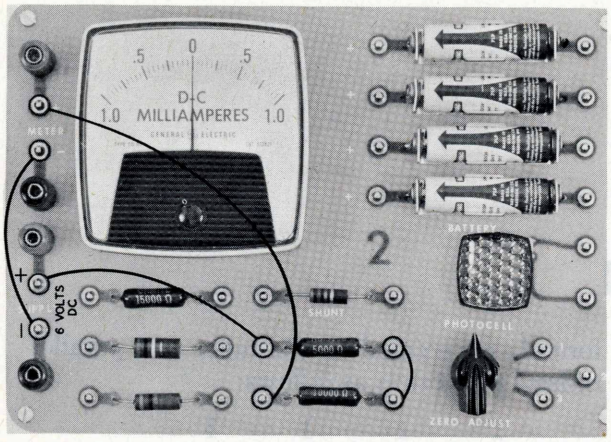
Procedure

1. Connect the following circuit:



Caution: ***Do not turn on the power supply until instructed to do so in the procedure for each experiment!***

2. Set the voltage control for the power supply at the minimum output, *turn on the power supply*, and slowly advance the voltage control to an output of 6 volts.
3. The circuit that you have just connected is a series resistance circuit containing a 10,000-ohm resistor and a 5,000-ohm re-



sistor. By use of the formula for series resistance, what is the equivalent resistance of these two resistors in series?

....

4. Using Ohm's Law, what should be the current through this series circuit?.................

.... What current is flowing in the circuit as indicated by the reading on the milliammeter?..............................

.... If there is any difference in these two values, what would account for such a difference?..............................

....

....

....

5. Set the multimeter to read 0-10 volts DC (see instructions in the introduction section of this manual). Being careful of the polarity, read the voltage across the 5000-ohm resistor. What is the voltage?

....

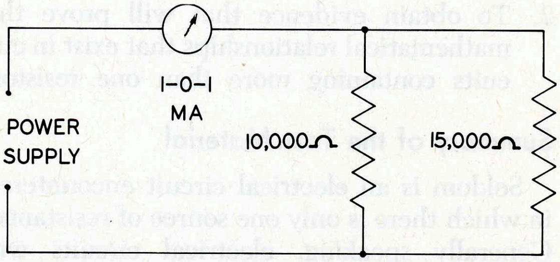
6. Read the voltage across the 10,000-ohm resistor. What is this voltage?

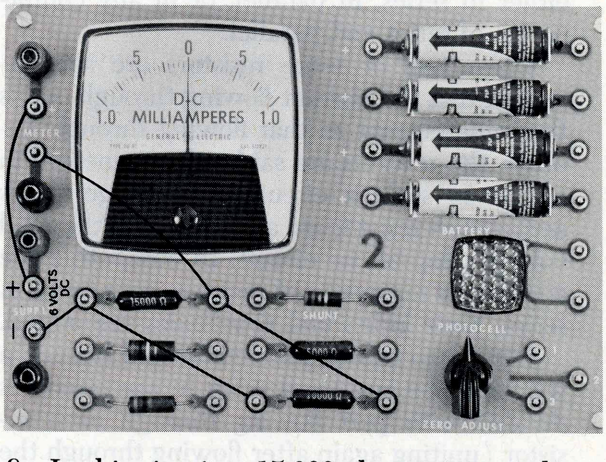
....

By Ohm's Law, using the value of current found in Step 4 and the resistance of the resistor (10,000 ohms), what should be the voltage across the 10,000-ohm resistor?

....

7. *Turn off the power supply.* Disconnect the circuit you have been using and connect the following:





8. In this circuit, a 15,000-ohm resistor and a 10,000-ohm resistor have been connected in parallel to form a parallel resistance circuit. *Turn on the power supply* with the output adjusted to 6 volts DC. What is the current in the circuit as determined by reading the milliammeter?

....

9. Using the formula for parallel resistance, what is the equivalent resistance of a 10,000-ohm resistor and a 15,000-ohm resistor when connected in parallel?

....

By Ohm's Law, using the value of current found in Step 8 and the source voltage of 6 volts, what is the value of the resistance in the circuit?

....

Is this the same value of resistance found by using the formula for parallel resistance?

....

If there is a difference, what would account for such a difference?

....

....

Turn off the power supply.

10. Disconnect all circuits used, and return all equipment to its proper storage place.

Summary

1. What happens to the voltage and the current in a series resistance circuit?

....

....

....

....

....

....

2. What happens to the voltage and the current in a parallel resistance circuit?

....

....

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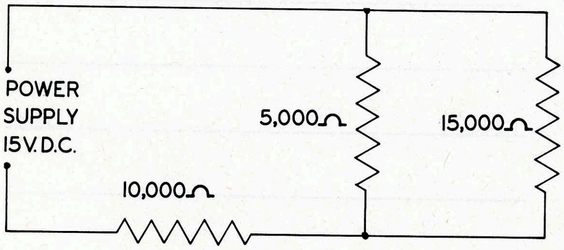
....

Additional Experiments in the Nature of Electricity

1. Determine the local cost of electricity and calculate the cost of operating a 100-watt lamp for 24 hours.

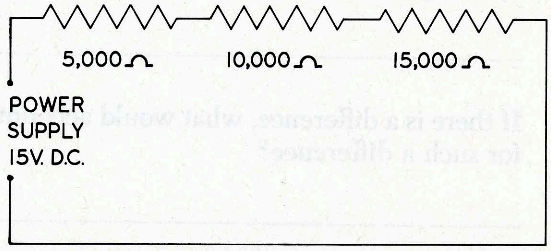
$$\text{Cost} = \left(\frac{\text{Cost}}{\text{per KWH}}\right)\left(\frac{\text{Watts}}{1000}\right)\left(\frac{\text{Time}}{\text{in hours}}\right)$$

2. Obtain a number of resistors from your instructor and using the standard color code (page 29 of the textbook), determine the value of each resistor.
3. Connect the following series-parallel resistance circuit.



Determine the value of current and voltage for each resistance by Ohm's Law and then measure the voltage across each resistor and the current through the resistor to check your mathematical solutions.

4. Connect the following series resistance circuit.



Determine the value of current and voltage for each resistance by Ohm's Law and then measure the voltage across each resistor and the current through the resistor to check your mathematical solutions.

Further Investigations in the Nature of Electricity

1. Chart the change in resistance due to the change in temperature of a filament of a lamp connected to a varying source of voltage.
2. Demonstrate the effect of length, cross-sectional area, and temperature on the resistance of various materials.
3. Plot, on graph paper, the change in resistance with a variation in the temperature of a thermistor. (Obtain thermistor from your instructor.)
4. Connect a circuit with two voltage sources as described in Problem 14 and also in the textbook on page 40 and test the circuit for all values of voltage and current and thus prove Kirchoff's Laws. (Use values of resistance that are available on Circuit Board 2.)

Problems in the Nature of Electricity

1. An ammeter connected in a direct current circuit indicates a current of 2 amperes. How many electrons will pass through the meter in 5 seconds?

....

....

2. If a circuit is connected using a battery of 9 volts as the source and has a total circuit resistance of 18 ohms, how much current exists in the circuit?

....

3. What voltage is necessary to force 2 amperes through 4 ohms of resistance?

....

4. What resistance would limit the current in a circuit to 2 amperes when the source voltage is 10 volts?

....

5. What power is consumed in a resistor which is connected to a source of 10 volts and has a current of 3 amperes flowing through it?

....

6. What current flows through a 100-watt lamp when connected to a source of 120 volts?

....

7. What power is consumed in a resistor of 10 ohms with 2 amperes flowing through it?

....

8. Three resistors with ratings of 10,000 ohms, 18,000 ohms and 22,000 ohms are connected in series. What is the total resistance?

....

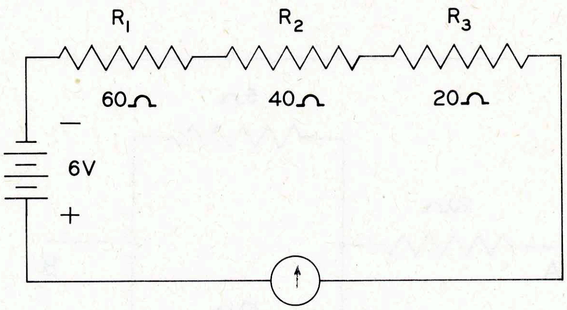


Fig. 1

9. In Fig. 1, the applied voltage is 6 volts. First determine the current in the circuit, then the individual voltage drop for each resistor.

....

....

....

....

....

10. What is the equivalent resistance of a 20-ohm and a 30-ohm resistor connected in parallel?

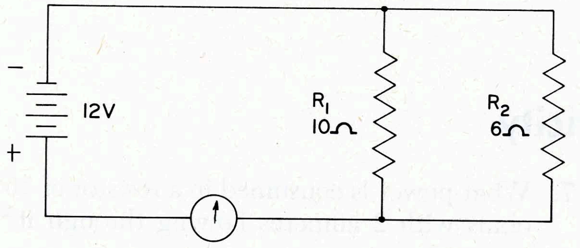


Fig. 2

11. In Fig. 2, determine the amount of current in each resistor and the total current in the entire circuit as indicated on the ammeter.

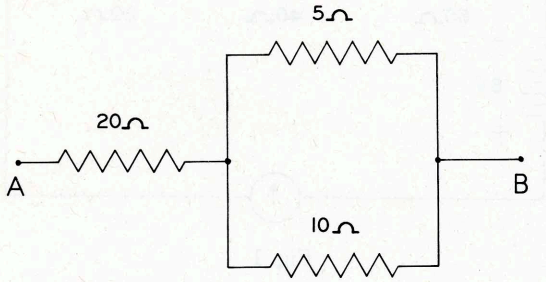


Fig. 3

12. In Fig. 3, what is the resistance between points *A* and *B*?

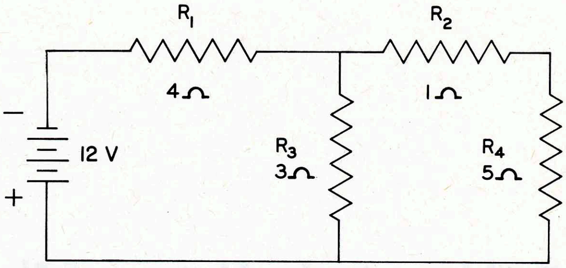


Fig. 4

13. In Fig. 4, determine the voltage drop and current in each resistor. (First determine the equivalent resistance of the circuit and then the total current in the circuit.)

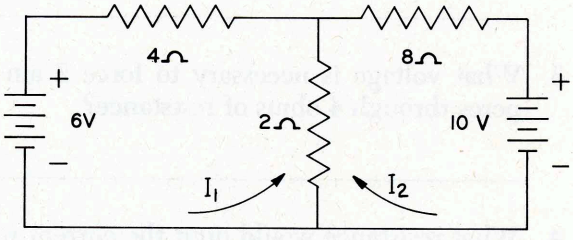


Fig. 5

14. In Fig. 5, determine the magnitude and direction of the current through the 2-ohm resistor.

Experiment 5

Basic Magnetism

Purposes

1. To study the process of magnetic induction.
2. To test common materials to determine whether they are magnetic or nonmagnetic.

Summary of the Text Material

A magnet may be identified by its ability to attract (to pick up) a piece of magnetic material. The ability of a material to be magnetic is called its permeability. Steel, iron, and other materials have a high permeability and therefore are considered to be magnetic. Some materials have a very low permeability and these materials are termed nonmagnetic. In this experiment, you will test a number of common metals and other materials to determine whether or not these materials are magnetic.

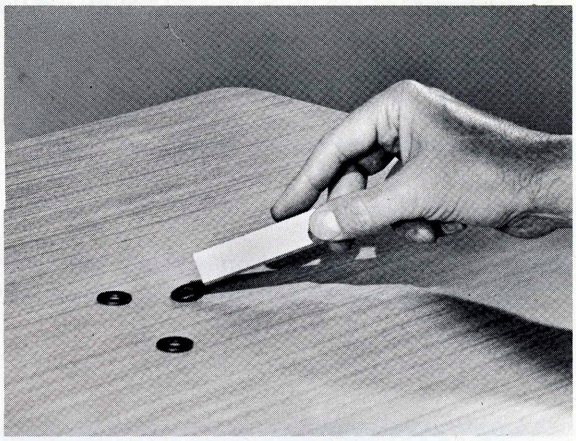
A piece of magnetic material can be magnetized by rubbing it with a magnet. This process is called magnetic induction. This was the first practical method of making a magnet. In this experiment, you will make a magnet by magnetic induction and will use this magnet to investigate certain magnetic properties.

The largest concentration of the magnetic field about a magnet exists at the end of the magnet which is called the *magnetic pole*. In this experiment you will observe the concentration of magnetic flux which exists at the poles of the magnet.

Equipment Required

(Included with Circuit Boards 1, 2, and 4)

1. Bar Magnets (4)
2. Carbon Strip (1)
3. Zinc Strip (2)
4. Copper Strip (2)
5. Lead Strip (4)
6. Aluminum Strip (1)
7. Iron Strip (4)
8. Nickel Strip (4)
9. Tin Strip (4)
10. Plastic Rod (1)
11. Wood Rod (1)
12. Hard Steel Rod (2)
13. Iron Washers (4)



Procedure

1. Spread a few iron washers on the top of the table. Holding a bar magnet in the hand, approach one of the iron washers with the end of the magnet. Is there any attraction between the magnet and the iron washer?

   ....

   Bring more iron washers to the end of the magnet. Are they also attracted?

   ....

How many washers can the bar magnet hold up at one time?..............................

2. Reverse the end of the magnet and determine if the opposite end of the magnet will attract the same number of iron washers. Is there any difference in the strength of the magnetism at the two poles?

....

From this observation could you say that the magnetic flux is the same at each pole of the magnet?

....

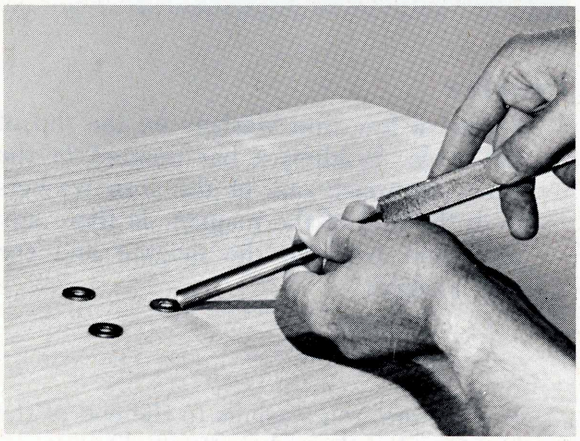
3. Can the center of a magnet attract any washers?.............................. Why would this be true?..............................

....

....

4. Try to pick up an iron washer with the hard steel rod. Can it attract any washers?

....

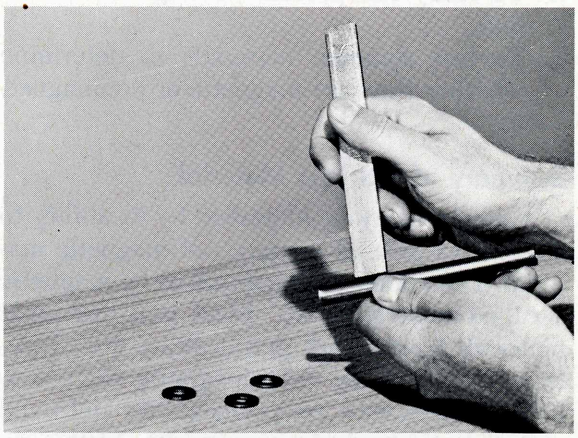


Hold the end of the bar magnet to the end of the hard steel rod, and with the opposite end of the hard steel rod, again try to pick up an iron washer.
Is there any attraction of the iron washer? .... Why would this be so?

....

....

5. Rub the hard steel rod with the bar magnet as shown in the photograph below.



Will the steel rod now attract an iron washer?..............................

Has the steel rod now become a magnet? .... Will either end of the steel rod attract a washer?

....

6. Magnetism can be destroyed in a magnet if the magnet is subjected to a physical jarring sufficient to cause a movement of the domains of the magnet. Throw the hard steel rod forcibly to the floor several times. Try again to pick up a washer with the hard steel rod. Does it now attract the washer as readily as before?

....

Can magnetism be destroyed in a magnet by physical abuse?..............................

7. Use a bar magnet to test the materials in the column below to determine whether or not they are attracted by the magnet. Record your observations in the space provided and indicate in the right column whether the materials tested are magnetic or nonmagnetic.

Material	Attracted by Magnet	Magnetic or Nonmagnetic
(a) Carbon		
(b) Zinc		
(c) Copper		
(d) Lead		
(e) Aluminum		
(f) Iron		
(g) Nickel		
(h) Tin		
(i) Plastic		
(j) Wood		

8. Clean all the equipment and materials and return them to their proper places.

Summary

1. What is magnetic induction? What is the procedure for making a magnet by magnetic induction?

....

....

....

....

....

....

....

....

2. What characteristics must a material have for it to be magnetic?

....

....

....

....

3. What is the relationship between the pole of a magnet and the strength of its magnetic field?

....

....

....

Experiment 6

Magnetic Attraction and Repulsion

Purposes

1. To study the attraction and repulsion of magnetic poles.
2. To observe the flux patterns of two magnets when their poles attract and when their poles repel.

Summary of the Text Material

The use of a small permanent magnet to pick up bits of iron or steel is familiar to most persons and was demonstrated in the previous experiment. Certain laws of magnetism other than this basic attraction for magnetic material are quite easily understood and can be worked with. As with electricity, however, we need to know how magnetism acts in order to be able to use it.

The basic law of magnetism is that the magnet, regardless of its physical shape or size, has concentrations of magnetic flux called poles, occurring at particular spots, generally at the ends. These concentrations of flux, or poles, have certain characteristics. Some poles will attract other poles, but some poles will repel other poles. By this means the poles may be easily classified and the simple statement of what happens is a basic law of magnetism. *Like poles repel — unlike poles attract.*

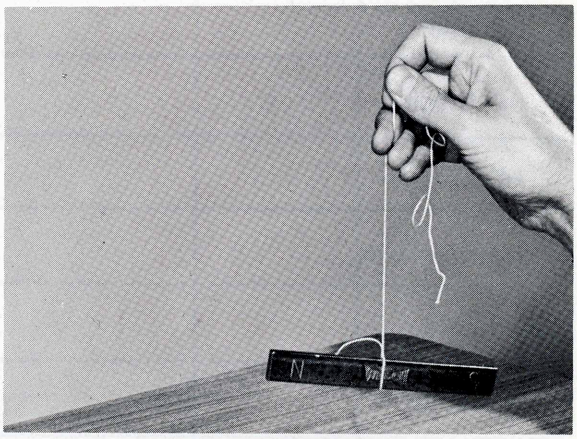
In this experiment you will make a very crude compass, in which a bar magnet will be used to demonstrate magnetic attraction and repulsion. Also, by use of iron filings, you will investigate the action of the flux field when two poles are attracting and when two poles are repelling.

Equipment Required

1. Bar Magnets
2. String
3. Paper — 5″ x 8″
4. Iron Filings

Procedure

1. Tie a short piece of string around the center of a bar magnet as shown in the photograph below. Hold the magnet by the string so that the magnet is free to rotate.



Eventually, the magnet will come to rest pointing in a certain direction. Observe the markings on the ends of the magnet. Which pole points in a northerly direction?

....

2. Continue holding the bar magnet suspended by the string as in Step 1. Holding the other bar magnet in the other hand, bring the north pole of the magnet in the hand toward the north pole of the magnet that is suspended by the string. What happens?

....

....

What does this indicate since the two poles were the same?..........

....

3. Repeat the action in Step 2, only approach the north end of the suspended magnet with the south pole of the magnet held in the hand. What happens this time?

....

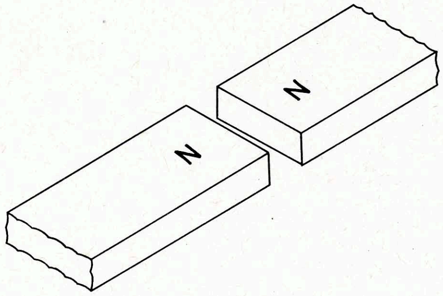
....

Since the two poles were opposite poles, what would this indicate?..........

....

....

4. Remove the string from the suspended bar magnet and place the two magnets on the table as shown in the Figure below.

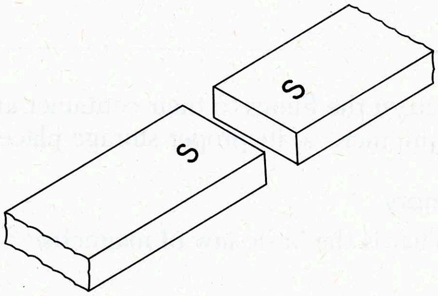


Cover the ends of the magnets that are close together with a piece of paper about 5″ x 8″. Sprinkle iron filings on the top of the paper. Observe the pattern that the iron filings make. Sketch this pattern on the Figure above. Since the two poles are the same, what does the flux pattern revealed by the iron filings indicate?

....

....

5. Remove the paper and iron filings, carefully returning the filings to their container. Reverse the two magnets so that the two south poles are facing each other, but not quite touching, as in the Figure below.

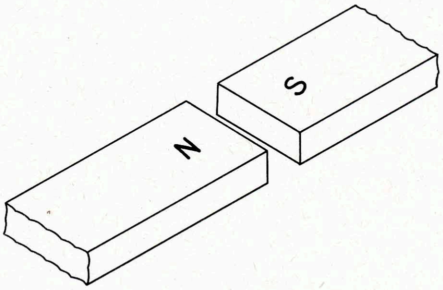


Cover the ends of the magnets with a sheet of paper as before and again sprinkle with iron filings on the top of the paper. Sketch the pattern made by the iron filings on the Figure above. Since again these were two like poles, what does the pattern of the iron filings in the flux field indicate?

....

....

6. Remove the paper as before and return the filings to their container. Reverse one of the two magnets so that a north pole is in close proximity to a south pole as in the Figure below.



Cover the ends of the magnets with a sheet of paper as before and again sprinkle iron filings on the paper. Sketch the pattern made by the iron filings on the Figure above. Since these were two unlike poles, what does the pattern of the iron filings in the flux field indicate?

7. Return the filings to their container and all equipment to its proper storage place.

Summary

1. What is the basic law of magnetism?

2. In view of the basic law of magnetism, how would you explain the operation of a magnetic compass?

Experiment 7

Electromagnetism

Purposes

1. To become familiar with the physical structure of an electromagnet.
2. To demonstrate the effect of the ampere turns of the electromagnet upon its strength.

Summary of the Text Material

When a coil of wire is wound about a core of magnetic material and a current is passed through this coil of wire, the result is an *electromagnet.* The strength of the magnet is dependent upon the number of turns of wire in the coil and the amount of current that is passing through the coil.

The polarity of the magnetic flux of an electromagnet is dependent upon the *direction of the current flow* through the coil.

Electromagnets are widely used in electrical and electronic circuits and devices. Electromagnetism is the basic principle used to convert electrical power into physical movement. Electromagnets are found in doorbells, buzzers, relays, motors, and other familiar electrical devices.

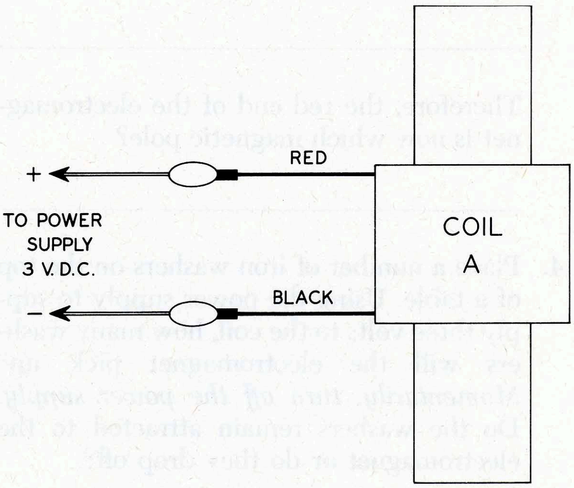
In this experiment, you will make an electromagnet and test its polarity and its strength. Then you will increase the current to observe the change in strength, and then increase the number of turns of wire in the coil to observe the change in strength of the electromagnet.

Equipment Required

1. Power Supply
2. ¾″ Square Laminated Core (Board 3)
3. 2 A coils (Board 3)
4. Iron Washers (Board 4)
5. Bar Magnet (Board 4)

Procedure

1. Place the ¾″ laminated core in one *A* coil. Hold the coil and bar in such a position that the red wire from the coil is pointed upward, as shown below.



Connect the red lead from the coil to the positive terminal of the power supply and the black lead to the negative terminal of the power supply, using clip leads. *Turn the voltage control of the power supply to "minimum." Turn on the power supply.* Adjust the output of the power supply to three volts DC.

2. Use the bar magnet and the law of magnetic attraction and repulsion to determine whether the red end of the coil is a north pole or a south pole. Which end of the bar magnet was attracted to the red end of the electromagnet?

....

Is the red end of the electromagnet a north

pole or a south pole?..

3. *Turn off the power supply.* Reverse the connections to the coil of the electromagnet in such a way that the red lead is connected to the negative terminal of the power supply and the black lead is connected to the positive terminal of the power supply. *Turn on the power supply* with the output set at 3 V DC. Repeat the same procedure as before and determine whether the red end of the coil is a north or a south magnetic pole. Which pole of the bar magnet does the electromagnet now attract?

....

Therefore, the red end of the electromagnet is now which magnetic pole?

....

4. Place a number of iron washers on the top of a table. Using the power supply to supply three volts to the coil, how many washers will the electromagnet pick up? *Momentarily, turn off the power supply.* Do the washers remain attracted to the electromagnet or do they drop off?

....

5. *Turn on the power supply and adjust the output voltage to six volts.* Again, test to see how many washers the electromagnet will pick up.

....

Is the magnet now stronger?

....

Why would the increase of voltage cause the magnet's strength to change?

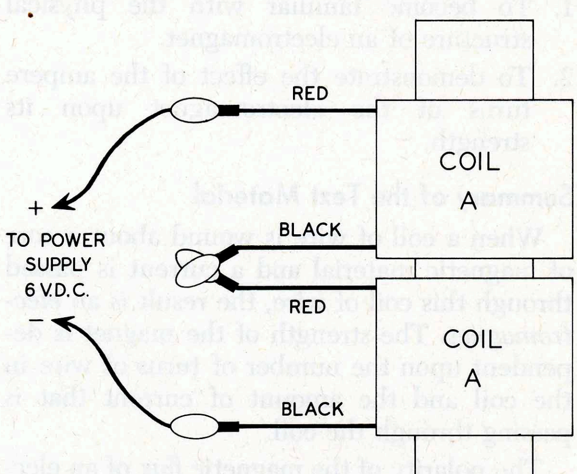
....

....

....

Turn off the power supply.

6. Disconnect the electromagnet and place a second *A* coil on top of the first on the core. Connect the coils so that the red lead of one goes to the black of the other (series connection). Connect the electromagnet to the power supply as shown below.



7. *Turn on the power supply and adjust the output voltage to six volts.* This is the same voltage used in Step 5. How many washers will the two-coil electromagnet attract?

....

This electromagnet has twice as many windings as the one in Step 5. How does the number of windings affect the strength of an electromagnet?

....

....

....

8. *Turn off the power supply.* Disconnect the circuit and return all equipment and materials to their proper storage places.

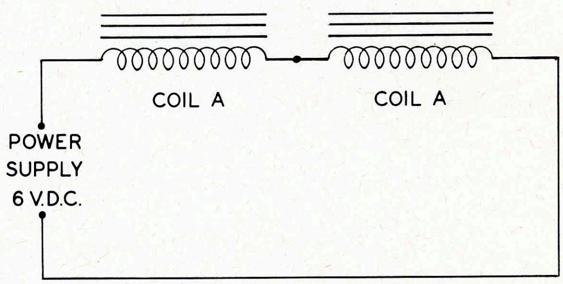
Summary

1. Upon what does the strength of an electromagnet depend?

2. Upon what does the polarity of an electromagnet depend?

Additional Experiments in Magnetism

1. Examine an electric bell. Draw a diagram of the bell showing the current path in the bell and explain the action of the bell.
2. Fill a test tube with iron filings. Show how it can be magnetized by induction, and how it can be demagnetized by agitation.
3. Set up an electromagnet on the center pole of the inductor unit of Circuit Board 3 as shown in the diagram given. Connect the electromagnet to the power supply and adjust the voltage to 6 volts DC. This electromagnet can be used the same as a permanent magnet for magnetic induction. Place the ¾″ laminated bar on the inductor so that it covers the pole pieces and observe the strength of this electromagnet.



Further Investigations in Magnetism

1. Obtain a 12″ length of tool steel about ½″ in diameter and hold it in a north-south position with the north end pointing toward the floor at about a 45° angle. Strike the end of the rod with a hammer several times and then test the rod to see if it has been magnetized.
2. Magnetize a piece of tool steel and then heat the steel in a furnace until the rod is cherry red. Once again test for magnetism.
3. Examine the relay on Circuit Board 1 and identify the electromagnet. Connect a source of 6 volts DC to the relay coil and explain the resulting action.

Experiment 8

The Ammeter

Purpose

1. To become familiar with the operational characteristics of an ammeter.

Summary of the Text Material

The familiar electrical meter is a current sensitive device. Meter movements vary in sensitivity. The one used on Circuit Board 2 has a full-scale deflection of 1 milliampere. To measure currents larger than 1 milliampere, it is necessary to place a shunt resistance across the meter movement. This shunt must have the required resistance to give full-scale deflection when the current is much larger than can be safely measured by the meter movement itself. The resistance value of the shunt is determined by the rules for parallel resistance.

Characteristically, the shunt has a much lower resistance than the meter movement. Because of the resistance ratio between the shunt and the meter movement, most of the current will flow through the shunt, while only a portion of the current will flow through the meter movement.

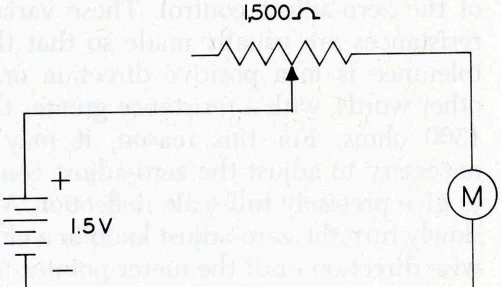
In this experiment you are going to use a shunt to show how a shunt affects the full-scale deflection of the meter movement. The basic meter movement of the circuit board you will use is a 1-0-1 ma. meter with an internal resistance of approximately 63 ohms. **Caution:** ***This meter can be easily damaged by any overload that occurs in the performance of this experiment. Follow the directions precisely, and do not hesitate to have your circuits checked by the instructor if you have any doubts.***

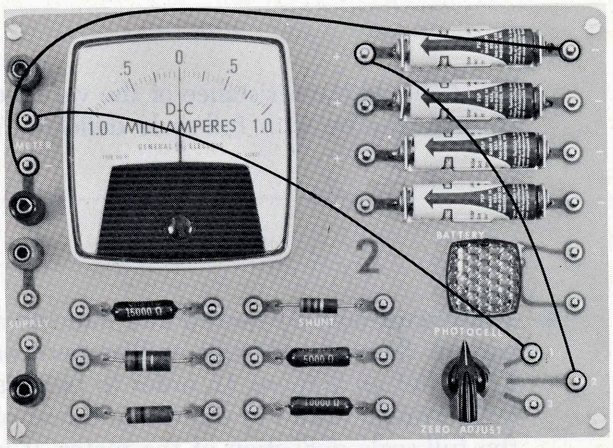
Equipment Required

Circuit Board 2

Procedure

1. Turn the zero-adjust control fully *counter-clockwise* – that is, so that the pointer is pointing toward the left. Connect the following circuit.





2. The zero-adjust control has a maximum resistance of 1500 ohms. With the connections as shown in Step 1, there is a com-

plete circuit on the circuit board, with a source voltage of 1½ volts and a resistance of approximately 1500 ohms. Using Ohm's Law, what amount of current should flow in this circuit?

....

....

What amount of current does flow in this circuit as indicated by the reading of the meter?

....

3. There may be some variation between the amount of current that should have been read and the amount of current as actually indicated on the meter due to the tolerance of the zero-adjust control. These variable resistances are usually made so that their tolerance is in a positive direction or, in other words, with a resistance greater than 1500 ohms. For this reason, it may be necessary to adjust the zero-adjust control to give precisely full-scale deflection. Very slowly turn the zero-adjust knob in a clockwise direction until the meter pointer rests exactly on the 1 ma. indication. Was it necessary to move the zero-adjust control very far?

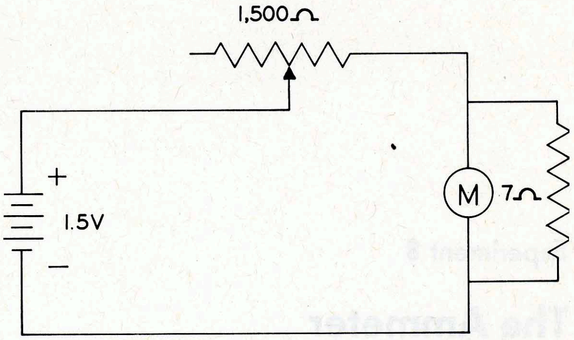
....

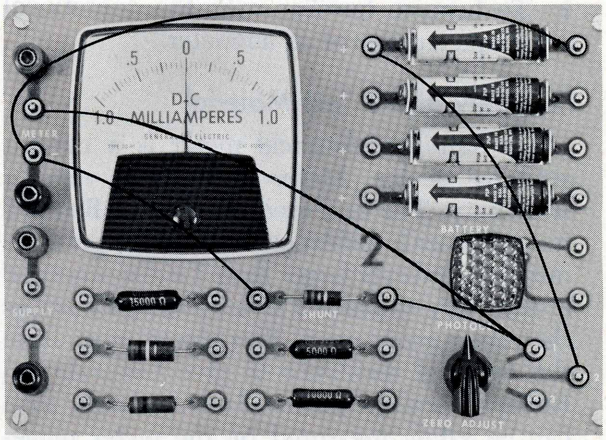
What should the resistance of the variable resistor now be with full-scale deflection?

....

....

4. The circuit now connected can indicate a current flow of only one milliampere or 1/1000 of an ampere. In order to be able to determine values of current in excess of the full-scale deflection of the meter, it is necessary to add a shunt.
5. Connect the shunt across the meter terminals as shown in the diagram below.





6. What happens to the deflection of the meter?

....

....

Why?..

....

NOTE: The voltage source and zero-adjust resistance used in this experiment are not part of the ammeter circuit itself. Only the shunt and the meter form an ammeter.

7. The meter movement used in this experiment has a resistance of 63 ohms. The shunt has a resistance of 7 ohms. Considered as resistors, this is a parallel resistance circuit. What is the resistance of the combination of these two resistances in parallel?

How does this value of equivalent resistance for these two resistors compare with the resistance of the meter movement?

....

....

....

8. Disconnect the circuit and return the circuit board and leads to their proper storage places.

Summary

1. What components are necessary in every ammeter?

....

....

....

2. What is the purpose of a shunt in an ammeter?

....

....

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....

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....

....

....

....

Experiment 9

The Voltmeter

Purposes

1. To become familiar with the functional characteristics of the voltmeter.
2. To become familiar with the physical characteristics of the voltmeter.

Summary of the Text Material

Almost all meters used in commercial activities are current-sensitive devices, regardless of the units indicated on the scale of the meter itself, which may be volts, counts per second, loaves of bread, amount of gasoline in a tank, or even temperature.

In utilizing a current-sensitive device as a voltmeter, it is necessary to add a resistor in series with the meter movement. An example may help to make this clear. The meter movement on Circuit Board 2 has a resistance of approximately 63 ohms. If this meter were placed across a potential of 300 volts, almost five amperes of current would flow through the meter and, obviously, ruin it. This is prevented by the series resistor (called a multiplier) which must be of sufficient size to limit the current to a safe value. For a 1 ma. meter, the ratio of ohms in a multiplier to voltage for full-scale reading would be 1000 ohms/volt. Thus, a meter with a full-scale deflection of 300 volts with a basic movement in which 1 ma. of current results in full-scale deflection, would need to have a 300,000-ohm resistor multiplier.

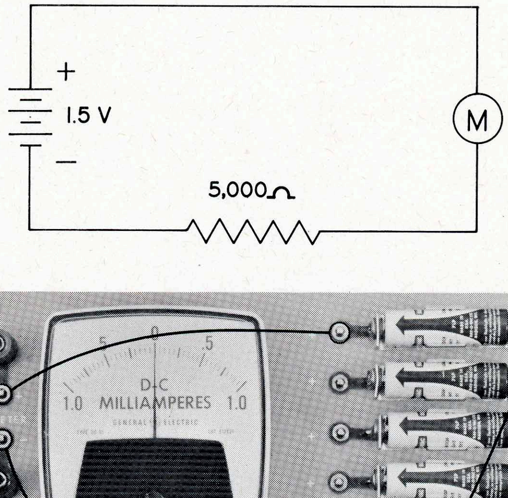
Any meter should be used with care and with skill. It is foolish to use a meter with a full-scale deflection of five volts to try to read 100 volts. The only result can be a damaged meter. Also, it might be pointed out that it would be foolish to try to read three volts on a 100-volt meter. The three-volt deflection would be hardly noticeable, but could be accurately read if the meter were a five-volt full-scale meter. *Be careful in this experiment not to overload the meter!*

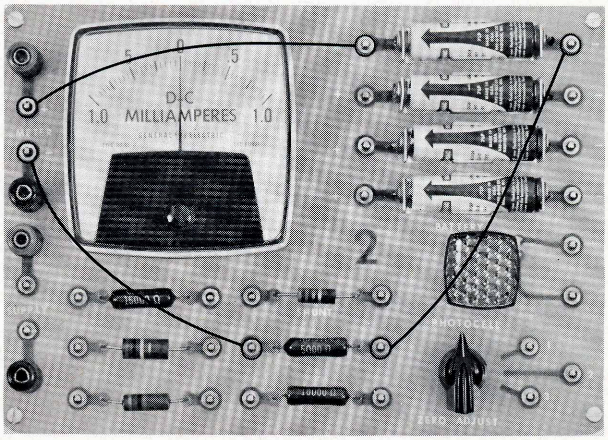
Equipment Required

1. Power Supply
2. Circuit Board 2
3. Test Prod Leads

Procedure

1. Set up the circuit as shown in the diagram below:





2. Determine by Ohm's Law the amount of current that should flow in the circuit.

How does this compare with the reading of the milliammeter?

....

How much voltage would be necessary to have full-scale deflection (with 1 ma)?

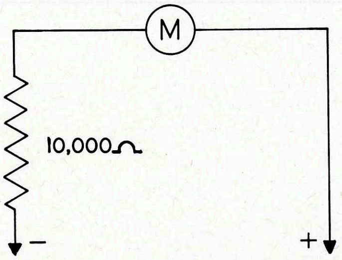
....

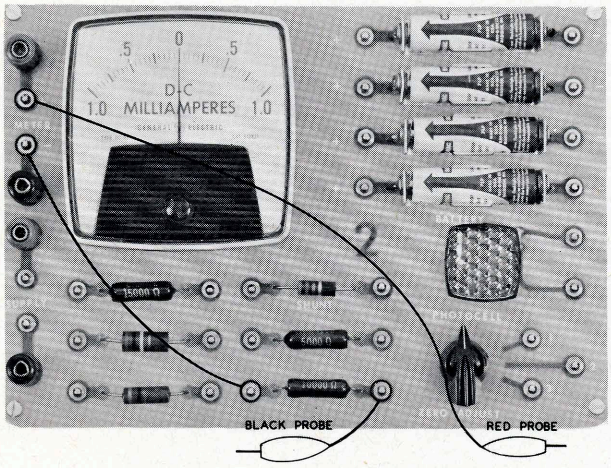
Since this is the amount of voltage necessary for full-scale deflection, the meter is a 0-5 volt DC voltmeter.

3. Since the meter is a 0-5 volt DC voltmeter, how much voltage does the voltmeter indicate for the source voltage of this circuit?

....

4. Change the circuit to the following:





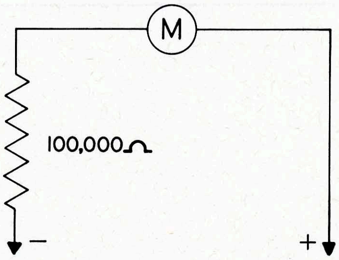
5. The circuit you have just connected is a 0-10 volt DC voltmeter. *Adjust the voltage control to its minimum output. Then turn on the power supply.* Slowly increase the voltage output of the power supply until it is 5 volts DC. Connect your voltmeter to the output terminals of the power supply. What is the reading of the voltmeter you have connected on the circuit board?

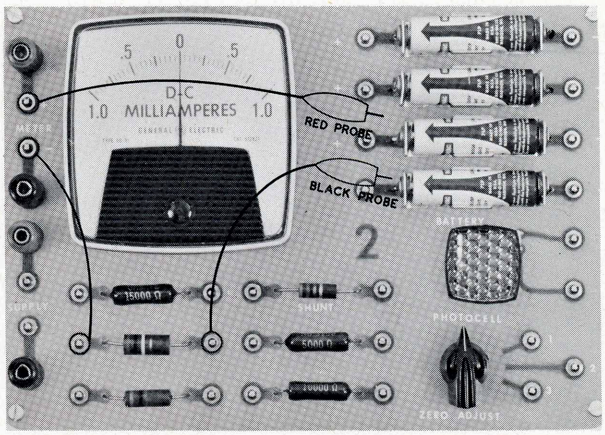
....

6. With the meter still connected to the power supply, slowly increase the output of the power supply to 10 volts. Compare the meter indicating the output of the power supply and the meter you have connected. Do they read the same value?

....

7. *Turn off the power supply.* Disconnect the meter you have made from the power supply and change the circuit to the following:





This is a 0-100 volt DC voltmeter. *Turn on the power supply and adjust the output to 10 volts DC.* Connect your meter to the power supply as in Step 6. What is the volt-

age reading of your meter now?

8. If you wanted to make a 0-1000 volt DC voltmeter, what would be the value of the multiplier resistor?

9. *Turn off the power supply.* Disconnect all circuits and return all materials and equipment to their proper storage places.

Summary

1. What components are necessary in a voltmeter?

2. What is the purpose of the multiplier resistor?

Experiment 10

The Ohmmeter

Purposes

1. To become familiar with the functional characteristics of the ohmmeter.
2. To become familiar with the physical characteristics of the ohmmeter.

Summary of the Text Material

The same basic meter movement that can be used to measure current and voltage can also be used to measure resistance. Close examination will show a similarity between the series ohmmeter and the circuit of a voltmeter. The major difference between the two circuits is that in the ohmmeter the source of voltage (therefore, current) is self-contained and that a portion of the circuit resistance is external. When the test prods of an ohmmeter are shorted together, the meter reads full scale indicating an external resistance of "0" ohms. When a resistance is placed between the leads equal to the internal resistance of the ohmmeter circuit, the meter reads half scale. If a resistance greater than the internal resistance of the ohmmeter circuit is placed between the test prods, the meter will read less than the half-scale deflection. If a resistance less than the internal resistance of the ohmmeter is placed between the test prods, the meter will read more than half scale. Unfortunately, the relationship between the reading of the meter and the amount of resistance in the external circuit is not a linear relationship. In other words, a graph of the meter readings and the resistance will not be a straight line.

In this experiment, you will construct a series ohmmeter and test it to see how it operates. In order to read the meter, you will use a graph showing the relation of the external resistance to the reading on the meter scale.

The multimeter that you use in your laboratory work to measure voltage, current, and resistance has a series ohmmeter built into it (the R x 1 and R x 10 ranges) in order that the unit may be used to read resistance. For this purpose, one of the scales of the meter has been calibrated directly in ohms.

The ohmmeter must be used only to measure resistance; indeed, if a multimeter is set to read ohms and used instead in an attempt to measure voltage, the only result will be a damaged meter movement. This is one way in which many multimeters are damaged. A student in electricity must be careful never to use an ohmmeter in an improper fashion.

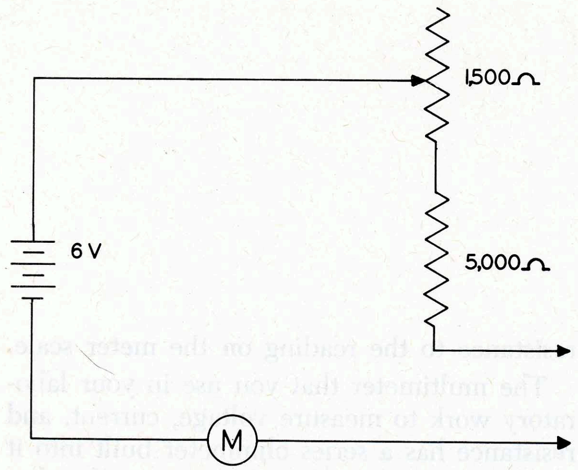
Equipment Required

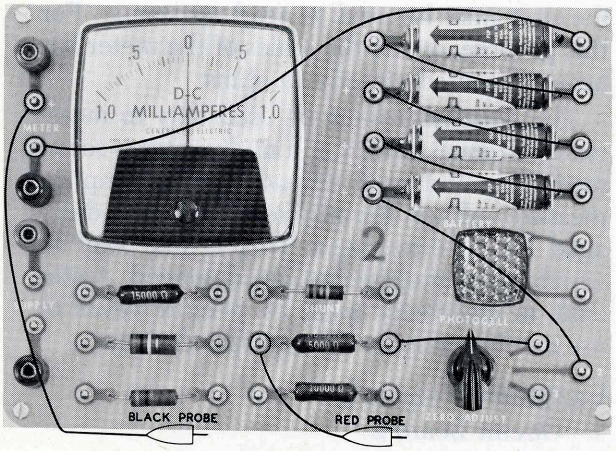
1. Circuit Board 2
2. Test Prods
3. Several Resistors of Known Value (Board 2)

Procedure

1. Turn the zero-adjust control fully counterclockwise; that is, so that the pointer is pointing toward the left. Connect the circuit shown on the next page.
2. Carefully examine the circuit as you make the connections. This is the circuit of a series ohmmeter. The cells have been connected in such a way that they are now capable of producing 6 volts DC (series connection). Using a 1 ma. basic meter movement, what resistance in a voltmeter circuit would give full-scale deflection when connected to 6 volts DC?

....





With the 5000-ohm resistor connected in series with the zero-adjust potentiometer which has a maximum resistance of 1500 ohms, how much resistance is there in series with the meter movement?

....

3. Short the test prods together. What is the action of the meter?.................... How much current does the meter indicate is flowing in the circuit?..............................

4. Before using an ohmmeter, it must always be adjusted for exact full-scale deflection when the two test prods are shorted together (an external resistance of zero ohms). With the two test prods shorted together, slowly adjust the zero-adjust control clockwise until full-scale deflection is achieved. Your ohmmeter circuit is now correctly adjusted.

5. Before you can use the ohmmeter to measure resistance, it will be necessary to calibrate the meter in terms of ohms of resistance. Since it is impractical to make a calibrated scale on the meter face, you will have to use a calibration graph for your meter. The graph you will use will have values of resistance on the vertical axis and the resulting current in milliamperes on the horizontal axis. The calibration graph for the ohmmeter circuit of Step 1 appears at the top of the next page.

6. Carefully examine the graph. If you measure an unknown resistance and the meter of your ohmmeter indicates that a current of .5 ma is flowing in the circuit, what would be the resistance of the unknown resistor?

....

....

What would be the resistance if .40 ma of current were flowing in the circuit?

....

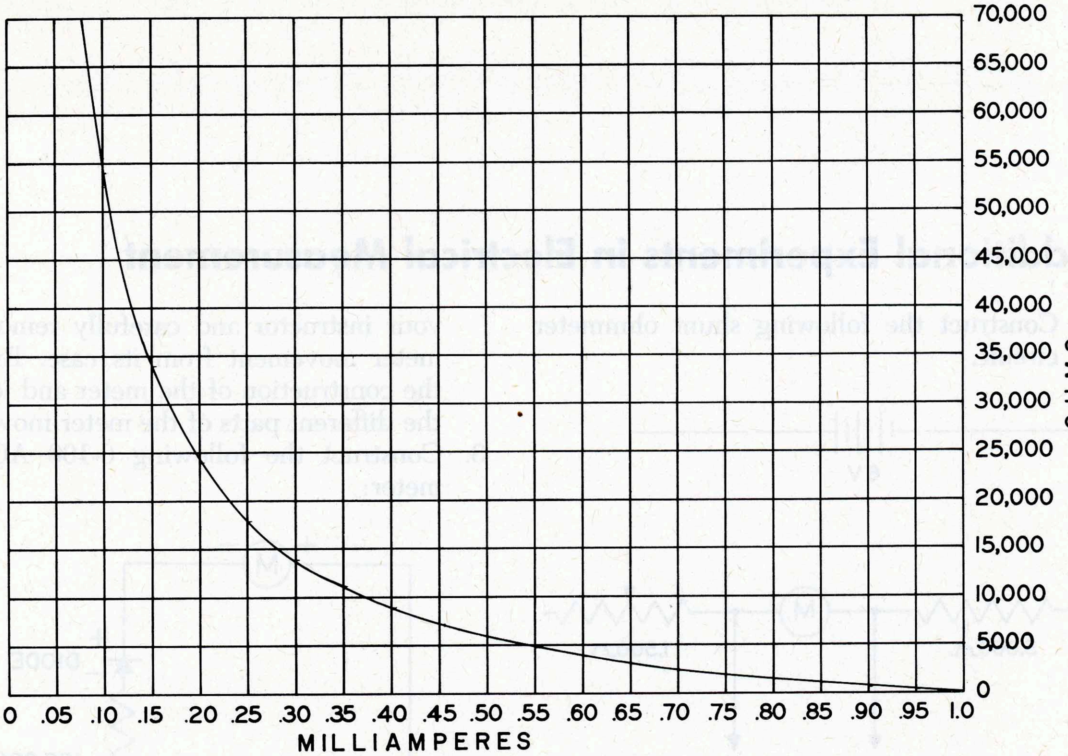
....

7. Obtain several resistors from your instructor and measure them using your ohmmeter circuit. How do the values of the resistance read on the meter compare with the value of the resistance marked on each resistor?

....

....

8. Disconnect the circuit that you have been using and return the circuit board and all other equipment and materials to their proper storage places.



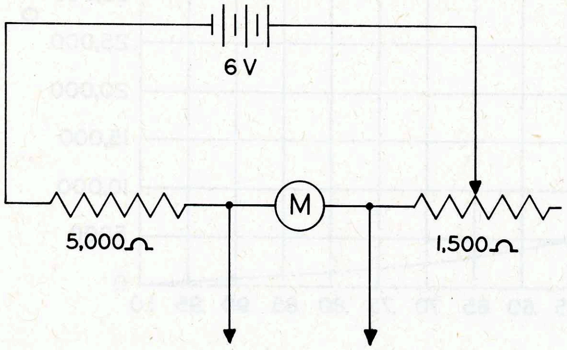
Summary

1. In what way are the circuits of the voltmeter and the ohmmeter similar?

2. If you had constructed an ohmmeter, how would you calibrate the scale?

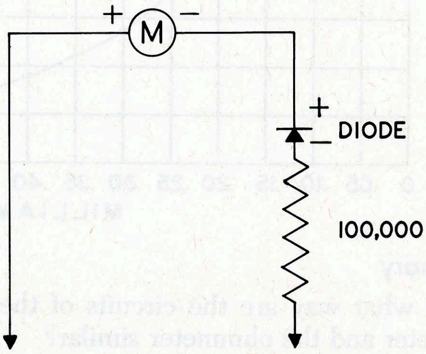
Additional Experiments in Electrical Measurement

1. Construct the following shunt ohmmeter circuit:



Make a calibration graph for the shunt ohmmeter by using the formula for parallel resistance. NOTE: The internal resistance of the 1-0-1 ma. meter on Circuit Board 2 is 63 ohms.

2. Obtain a surplus meter movement from your instructor and carefully remove the meter movement from its case. Examine the construction of the meter and identify the different parts of the meter movement.
3. Construct the following 0-100 AC voltmeter:



NOTE: The diode on Circuit Board 1 can be used as the diode in the circuit above.

Further Investigations in Electrical Measurement

1. Examine the diagram of the Eico model 526A multimeter which appears in the introductory chapter of this manual (page 16) and draw the diagram of the voltmeter circuit for 0-100 DC volts (Switch Position 8).
2. Examine the diagram of the Eico model 526A multimeter and draw the diagram of the ammeter circuit for 0-100 milliamperes.
3. Examine the diagram of the Eico model 526A multimeter and draw the diagram of the ohmmeter circuit for R x 10, (1,500 ohms mid-scale deflection).

Problems in Electrical Measurement

1. What value of resistance would be necessary to form a shunt for a 0-100 ma. meter made from a 0-1 ma basic meter movement with 100 ohms internal resistance?

....

2. A 0-10 ma. meter has a resistance of 5.0 ohms. The basic movement is a 0-1 ma. meter. What is the resistance of the basic meter movement and the resistance of the shunt?

....

3. What multiplier is required to make a 0-6 volts DC voltmeter from a 0-1 ma. basic meter movement? Disregard the resistance of the meter movement.

....

4. What multiplier is required to make a 0-5 volt DC voltmeter from a 0-2 ma. basic meter movement which has an internal resistance of 50 ohms?

....

5. What multiplier is necessary to make a 0-10 volts AC voltmeter from a 0-1 ma. basic DC movement with an internal resistance of 100 ohms? The rectifier has a resistance of 25 ohms.

....

6. A series ohmmeter built from a 0-1 ma. basic movement has a mid-scale reading of 4500 ohms.
   a. What is the internal resistance of the circuit?

   ....

   b. What is the emf of the internal battery for this ohmmeter circuit?

   ....

7. An ammeter designed to read 0-50 ma. can be made from a 0-1 ma. basic meter movement with the proper shunt. What is the total current through the ammeter when 0.4 ma. is flowing through the meter movement?

....

8. You find it necessary to measure up to 5000 volts for a project you have constructed. Your only meter is a 1000 ohm-per-volt, 0-1000 volt meter. How much resistance must be placed in series with the meter leads to produce a 0-5000 volt meter?

....

NOTE: Should you ever use this procedure, always make your connections before the circuit is energized, and remove the connections only after the circuit is de-energized.

Experiment 11

The Inductor

Purposes

1. To become familiar with the physical characteristics of an inductor.
2. To investigate the self-inductance of an inductor.
3. To investigate the action of inductance in AC and DC circuits.

Summary of the Text Material

Inductance is that property of a circuit which opposes any change in the amplitude of the current flowing through the circuit. Inductors resemble large electromagnets in their physical appearance. If you were to take apart an inductor to study its construction, you would find that it is a single coil of wire wound about a laminated core of high-grade silicon steel. In some ways you would find its appearance much the same as a transformer.

The only sure way of telling a commercial transformer and a commercial inductor apart is by one characteristic of the inductor – the inductor has only two connections while the transformer will have four or more.

Inductance owes its operating characteristics to the fact that it is a magnetic device. As you discovered in the experiment on electromagnetism, the flux of an electromagnet is dependent upon the amount of current flowing through the coil. When a certain amount of current is flowing through the inductor, any increase of current must increase the amount of flux. Time is required to change the amount of flux; and until the change is complete, the inductor tends to resist the change in the amount of current flowing in it. The larger the inductor, the larger this inductive effect.

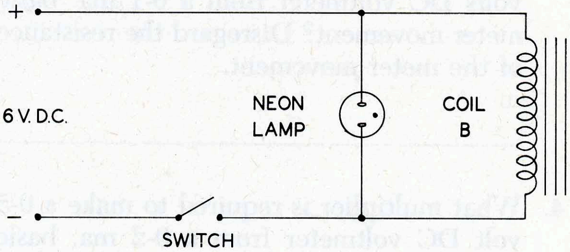
In this experiment you will make an inductor and experiment with the effects of self-inductance. Also in this experiment you will observe the difference when an inductor is passing an alternating current and when it is passing a direct current.

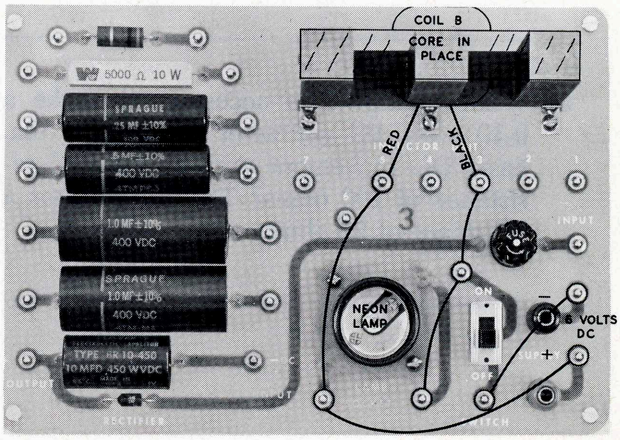
Equipment Required

1. Circuit Board 3
2. Power Supply
3. 1 Coil *B*
4. Neon Lamp
5. 60-Watt Lamp
6. ¾″ Laminated Core

Procedure

1. Connect the following circuit:





APPENDIX C

UNIT ASSIGNMENT SHEET FOR TREATMENT A

UNIT OUTLINE

Introduction

Due to the increasing use of electricity-electronics equipment, it is evident that the basic fundamentals of electricity are worthy of study.

Regardless of ones major field of interest, an understanding of basic electricity will be beneficial in both technical and domestic activities.

I. Nature of Electricity

A. Objective

This unit will introduce atomic structure, factors which determine electron action, basic terminology, and primary circuits.

B. Assignments

1. Read pages 15-19 in text.[1] Answer the review questions on page 41. Be prepared to discuss your answers in class.
2. Experiment 1. Read pages 9-18 in laboratory manual.
3. Read pages 19-22 in text. Answer review questions 11-15, and advanced questions 1-3.
4. Experiment 2. Study page 22 in Lab. manual before class.
5. Read pages 24-32 in text. Answer review questions 15-22. Read pages 32-38.
6. Experiment 3. Read carefully experiment 3 before class.
7. Read pages 32-41 in text. Answer questions 23-29, and advanced questions 4-11. Work the Ohm's Law problems on the assignment sheet given you.

[1] Rex Miller and Fred W. Culpepper, Jr., Energy, Electricity and Electronics (Bloomington, Illinois: McKnight and McKnight Publishing Co., 1964)

8. Experiment 4. Read pages 29-30 in Lab. manual before class.

9. Work problems 1-14 on pages 33-34 of Lab. manual.

10. Hand in Lab. manuals and the answers to all assigned problems

II. Magnetism

A. Objective

This unit deals with basic magnetic theory as applied to permanent magnets and electromagnets.

B. Assignments

1. Read pages 45-47 in text. Answer review questions 1-9, p. 51-52. In Turner read pages 68-73.

2. Experiment 5. Read pages 35-37 in Lab. manual

3. Experiment 6. Read pages 38-40 in Lab. manual

4. Read pages 48-51 in text, answer review questions 10-15, and advanced questions 1-12. In Turner read pages 73-84.

5. Experiment 7. Study pages 41-43 in Lab. manual.

III. Electrical Measuring Instruments. Project (volt-ohm-milliammeter)

A. Objective

This unit will introduce basic electrical measuring devices, including the ammeter, voltmeter, and ohmmeter.

*B. Assignments

1. Read pages 53-57 in text, answer review questions 1-5. In Turner read pages 333-341.

2. Experiment 8. Read pages 45-47 in Lab. manual.

*Shopwork on the project will take place during Monday, Wednesday, and Friday class periods.

3. Read pages 58-62 in text, answer review questions 6-13 and Adv. questions 1-6. In Turner read pages 341-355, work problems 2-3, p. 376.

4. Experiment 9. Read pages 48-50 in Lab. manual Work problem 4, page 376, in Turner.

5. Experiment 10. Read pages 51-53 in Lab. manual Work problem 9, p. 377, in Turner.

6. Work problem 1-9, p. 55, in Lab. manual.

APPENDIX D

UNIT OUTLINE FOR TREATMENT B

I. Nature of Electricity

A. Purpose

Unit I introduced the field of electricity, the atom, and terminology of electricity.

B. Assignment

1. Read text and references
2. Answer questions

C. Reading*

1. Text, Basic Electricity, Rufus P. Turner, pages 1-17.

2. Basic Electricity, Abraham Marcus, pages 1-21

3. Understanding Electricity and Electronics, Buban & Schmitt, pages 1-17, 115-131.

D. Questions

1. What is electricity?

2. What are the two types of electricity and what are they used for?

3. What is the difference between a conductor and an insulator?

4. What is the difference between energy and power?

5. Explain the characteristics of positive and negative charges.

6. Explain the structure of the atom and its bearing on the field of electricity.

7. What is an electrostatic field?

8. How is lightning generated?

9. How do volts and amps differ?

10. How fast does the electron travel in a wire?

11. How does an electroscope work?

*References are included in the BIBLIOGRAPHY.

12. Define the following and sketch symbol where applicable:

    a. Conductor or wire
    b. Terminal
    c. Cell and battery
    d. Switch
    e. Coil
    f. Tube and transistor
    g. Lamp
    h. Circuit
    i. Coulomb
    j. Ionization

II. Conductors and Insulators

A. Purpose

The conductor and insulator are the most basic components in any electrical system, this unit is devoted to their make-up and characteristics.

B. Assignment

1. Read text and references
2. Answer questions

C. Reading

1. Text, pages 15, 232, and 233.
2. Electricity and Electronics, Basic, Stenburg and Ford, pages 77-85.
3. Understanding Electricity and Electronics, Buban and Schmitt, pages 43-53.

D. Questions

1. How do insulators and conductors differ as to structure (atomic)?
2. Describe a wire gage.
3. What materials are used in conductors?
4. What types of wire coverings are commonly used?
5. What is a resistance wire?
6. What are some common insulation materials?

7. What is the difference between a wire and a cable?

8. Why is wire sometimes stranded?

9. What is magnet wire?

10. What is a semiconductor?

11. Define or describe:

    a. Hookup wire
    b. Coaxial Cable
    c. Ground Wire
    d. Shielded Wire
    e. Romex
    f. Bx
    g. Porcelain
    h. Mica
    i. Bakelite
    j. A. W. G.

III. Electrical Units and Their Measurements

A. Purpose

The electrical units have been introduced in earlier sections of this guide. This section is designed to examine their origin and the devices used in their measurement.

B. Assignment

1. Read text and references

2. Answer questions

C. Reading

1. Text pages 333-346

2. <u>Basic Electricity</u>, Abraham Marcus, pages 74-99, 162-177.

3. <u>Electronic Measuring Instruments</u>, Harold E. Soisson pages 182-189.

D. Questions
Explain the following terms

1. Volt

2. Ammeter Ampher.

3. Ohm

4. Watt

IV. Circuits

A. Purpose

The material in this unit is designed to introduce electrical circuits, their use, characteristics, calculations and measurements.

B. Assignment

1. Read text

2. Answer questions

3. Work problems

C. Readings

1. Text pages 18-22, 36-48.

2. Basic Electricity, Abraham Marcus, pages 40-50.

3. Understanding Electricity and Electronics, Buban & Schmitt, pages 144-155.

D. Questions

1. Compare voltage across series and parallel circuits.

2. Compare current in a series or a parallel circuit.

3. Compare total resistance of a group of loads in series and parallel.

4. What is ohms law and of what value is it?

5. What are kirchoff's laws?

6. Explain the power formula.

7. What is a bridge circuit?

8. What are the main assets of a series circuit?

9. What are the main assets of a parallel circuit?

10. What is meant by voltage drop?

E. Problems

1. Work problems on handout sheet.

2. Work problems pages 145 and 149 in Understanding Electricity and Electronics by Buban and Schmitt.

3. Work problems pages 49 and 50 in Basic Electricity by Abraham Marcus.

V. Generation of Electricity

A. Purpose

This unit introduces the various types of electrical generation and the generating devices from solar cell to atomic cell.

B. Assignment

1. Read text and references.

2. Answer questions.

C. Reading

1. Text pages 15-16, 22-31, 174-179.

2. Basic Electricity, Abraham Marcus, pages 16-17, 216-252.

3. Understanding Electricity and Electronics, Buban and Schmitt, pages 219-225.

D. Questions

1. Name and describe six sources of E. M. F.

2. What are the two types of chemical cells?

3. What is a fuel cell?

4. What type of material is used in photocells?

5. Why is electro-mechanical generation the most highly used form of power production?

6. Where are solar cells used?

7. Where are piezoelectric crystals used?

8. Explain the operation of the lead acid battery.

9. What is a hydrometer?

10. What is the electromotive series?

VI. Magnetism

A. Purpose

This unit introduces the area of magnetism and its importance in the total electrical picture.

B. Assignment

1. Read text and references

2. Answer questions

C. Reading

1. Text, pages 68-74

2. Basic Electricity, Abraham Marcus, pages 55-56.

3. Electricity and Electronics-Basic, Steinburg and Ford, pages 16-25.

4. Understanding Electricity and Electronics, Buban and Schmitt, pages 163-170.

D. Questions

1. What effect does magnetism have on the molecular structure of a ferromagnetic material?

2. What are the classes of magnetic materials?

3. What is a magnetic pole?

4. What is magnetic induction?

5. Name ten laws or rules that apply to magnets.

6. How does a compass work?

7. What is a dip needle?

8. What are two types of magnets?

9. What three ways can magnetism be destroyed?

10. How is magnetic shielding accomplished?

VII. Electrical Units and Their Measurement

A. Purpose

The electrical units have been introduced and earlier sections of this guide. This section is designed to examine the devices used in their measurement.

B. Assignment

1. Read text and references

2. Answer questions

C. Reading

1. Text pages 333-346

2. Basic Electricity, Abraham Marcus, pages 74-99, 162-177.

3. Electronic Measuring Instruments, Harold E. Soisson, pages 182-189.

D. Questions

Explain the function and use of the following instruments:

1. Voltmeter

2. Ammeter

3. Ohmmeter

4. Wattmeter

5. Tube Tester

6. Frequency Meter

7. Oscilloscope

8. Bridge Test Circuit

9. Signal Generator

10. Isolation Transformer

11. D. C. Power Supply

12. Signal Tracer

APPENDIX E

STUDENT PERSONNEL PLAN

STUDENT ORGANIZATION

General Supervisor -

1. Reports to teacher.
2. All foremen report to him.
3. Checks roll on shop days.
4. Approves or disapproves students leaving room.
5. Observes class operation and helps students with routine problems.
6. Unlocks tool and equipment cabinets.

Safety Foreman

1. Check machines at beginning and end of each period for unsafe conditions.
2. Check condition of hand tools peroidically.
3. Observe class operation for unsafe practices.
4. Watch for unsafe electrical set-ups.
5. Be responsible for 5 minute safety talk each week.

Clean-up Foreman

1. Check machines for cleanliness each period.
2. Check benches for cleanliness.
3. Check with tool foreman to see if tools are all in place.
4. Dismiss class.

Material and Tool Foreman

1. Check condition of hand tools.
2. Check condition of instruments as necessary.
3. Maintain tools where possible.
4. Check out materials as necessary
5. Keep records of materials used.

NOTICE TO ALL STUDENTS - The persons assuming the above duties also assume authority commensurate with these duties and are considered to be direct representitive of the teacher.

A. O. Brown III

APPENDIX F

COURSE SYLLABUS FOR "APPLIED ELECTRICITY 140"
OFFERED AT KANSAS STATE COLLEGE
OF PITTSBURG

COURSE SYLLABUS

BASIC APPLIED ELECTRICITY

COURSE NO. 140 (45)

THREE SEMESTER HOURS

A. O. BROWN III

INDUSTRIAL EDUCATION DEPARTMENT

MISCELLANEOUS INFORMATION

I. Grading - Grades are based on the following items:

   A. Unit tests 25%
   B. Final examination 25%
   C. Projects 25%
   D. Hand-in assignments, project write-ups and student organization participation 25%

II. Projects - Each project should be planned in advance. The project should follow the outline shown below:

   A. Description
   B. Use
   C. How it works
   D. Schematic drawing
   E. Parts list
   F. Price list
   G. Construction procedure

III. Absences - All absences will be made up as outlined by instructor.

IV. All assignments, project plans and projects are due before last class period.

V. All written assignments including special assignments should be properly noted to give credit to sources.

VI. Books and magazines checked out from office should be returned before the last class period. Note, materials can be checked out by filling out slip listing name of publication, date of publication, date checked out and name of person borrowing material.

I. Nature of Electricity

A. Purpose - Unit I introduces the field of electricity, the atom, and terminology of electricity.

B. Assignment -
1. Read text and references
2. Answer questions

C. Reading -
1. Text, Basic Electricity - Rufus P. Turner, Pages 1-17
2. Basic Electricity - Abraham Marcus, Pages 1-21
3. Understanding Electricity and Electronics - Buban & Schmitt, Pages 1-17, 115-131

D. Questions -
1. What is electricity?
2. What are the two types of electricity and what are they used for?
3. What is the difference between a conductor and an insulator?
4. What is the difference between energy and power?
5. Explain the characteristics of positive and negative charges.
6. Explain the structure of the atom and its bearing on the field of electricity.
7. What is an electrostatic field?
8. How is lightning generated?
9. How do volts and amps differ?
10. How fast does the electron travel in a wire?
11. How does an electroscope work?
12. Define the following and sketch symbol where applicable:
    a. Conductor or wire
    b. Terminal
    c. Cell & battery
    d. Switch
    e. Coil
    f. Tube & transistor
    g. Lamp
    h. Circuit
    i. Coulomb
    j. Ionization

II. Conductors & Insulators

A. Purpose - The conductor and insulator are the most basic components in any electrical system, this unit is devoted to their make-up and characteristics.

B. Assignment -
1. Read text and references
2. Answer questions

C. Reading -
1. Text, Pages 15, 232 & 233
2. Electricity & Electronics Basic-Stenburg & Ford Pages, 77-85
3. Understanding Electricity & Electronics, Buban & Schmitt, Pages 43-53

D. Questions -
1. How do insulators & conductors differ as to structure (atomic)?
2. Describe a wire gage.

3. What materials are used in conductors?
4. What types of wire coverings are commonly used?
5. What is a resistance wire?
6. What are some common insulation materials?
7. What is the difference between a wire and a cable?
8. Why is wire sometime stranded?
9. What is magnet wire?
10. What is a semiconductor?
11. Define or describe:
    a. Hookup wire
    b. Coaxial Cable
    c. Ground Wire
    d. Shielded Wire
    e. Romex
    f. Bx
    g. Porcelain
    h. Mica
    i. Bakelite
    j. A.W.G.

III. Magnetism

A. Purpose - This unit introduces the area of magnetism and its importance in the total electrical picture.

B. Assignment -
   1. Read text and references
   2. Answer questions

C. Reading -
   1. Text, Pages 68-74
   2. Basic Electricity-Abraham Marcus, Pages 55-56
   3. Electricity & Electronics - Basic, Steinburg & Ford, Pages 16-25
   4. Understanding Electricity & Electronics, Buban & Schmitt Pages 163-170

D. Questions -
   1. What effect does magnetism have on the molecular structure of a ferromagnetic material?
   2. What are the classes of magnetic materials?
   3. What is a magnetic pole?
   4. What is magnetic induction?
   5. Name ten laws or rules that apply to magnets.
   6. How does a compass work?
   7. What is a dip needle?
   8. What are the two types of magnets?
   9. What three ways can magnetism be destroyed?
   10. How is magnetic shielding accomplished?

IV. Generation of Electricity

A. Purpose - This unit introduces the various types of electrical generation and the generating devices from solar cell to atomic cell.

B. Assignment -
   1. Read text & references.
   2. Answer questions.

C. Reading -
1. Text Pages 15-16, 22-31, 174-179.
2. Basic Electricity - Abraham Marcus, Pages 16-17, 216-252.
3. Understanding Electricity & Electronics - Buban & Schmitt, Pages 219-235.

D. Questions -
1. Name & describe six sources of E.M.F.
2. What are the two types of chemical cells?
3. What is a fuel cell?
4. What type of material is used in photocells?
5. Why is electro-mechanical generation the most highly used form of power production?
6. Where are solar cells used?
7. Where are piezoelectric crystals used?
8. Explain the operation of the lead acid battery.
9. What is a hydrometer?
10. What is the electromotive series?

V. Electrical Units & Their Measurement

A. Purpose - The electrical units have been introduced in earlier sections of this guide. This section is designed to examine their orgin and the devices used in their measurement.

B. Assignment -
1. Read text & references
2. Answer questions

C. Reading -
1. Text pages 333-346
2. Basic Electricity - Abraham Marcus, Pages 74-99, 162-177.
3. Electronic Measuring Instruments - Harold E. Soisson, Pages 182-189.

D. Questions - Explain the function & use of the following instruments:

1. Voltmeter
2. Ammeter
3. Ohmmeter
4. Wattmeter
5. Tube Tester
6. Frequency Meter
7. Oscilloscope
8. Bridge Test Circuit
9. Signal Generator
10. Isolation Transformer
11. D.C. Power Supply
12. Signal Tracer

VI. Circuits

A. Purpose - The material in this unit is designed to introduce electrical circuits, their use, characteristics, calculations and measurements.

B. Assignment -
1. Read text
2. Answer questions
3. Work problems

C. Readings -
1. Text pages 18-22, 36-48.
2. Basic Electricity-Abraham Marcus, Pages 40-50.
3. Understanding Electricity & Electronics - Buban & Schmitt, Pages 144-155.

D. Questions -
1. Compare voltage across series and parallel circuits.
2. Compare current in a series or a parallel circuit.
3. Compare total resistance of a group of loads in series and parallel.
4. What is ohms law and of what value is it?
5. What are kirchoff's laws?
6. Explain the power formula.
7. What is a bridge circuit?
8. What are the main assets of a series circuit?
9. What are the main assets of a parallel circuit?
10. What is meant by voltage drop?

E. Problems -
1. Work problems on handout sheet.
2. Work problems pages 145 and 149 in Understanding Electricity and Electronics by Buban and Schmitt.
3. Work problems pages 49 and 50 in Basic Electricity by Abraham Marcus.

VII. Inductors & Capacitors

A. Purpose - In this unit the student is introduced to the inductor or coil and the capacitor. These two types of components are particularly important in the study of A.C. and along with the resistor and conductor make up the main components of any electrical system.

B. Assignment -
1. Read text and references.

C. Reading -
1. Text, Pages 100-138.
2. Understanding Electricity and Electronics - Buban & Schmitt, Pages 83-94, 138-143, 185-186, 249-250, and 321-325.
3. Basic Electricity - Abraham Marcus, pages 117-126, 128-158.

D. Questions -
1. What characteristics of a coil of wire contribute to its inductance?
2. What is inductive reactance?
3. What physical characteristics of a capacitor contributes to its capacitance?
4. What is capacitive reactance?
5. What is impedance?
6. What is phase shift?
7. What is a vector?
8. What electrical characteristics does resonance depend on?
9. Name five uses for inductors.
10. Name five uses for capacitors.
11. List the units for the following:
    a. Capacitance
    b. Inductance
    c. Impedance
    d. Capacitive Reactance
    e. Inductive Reactance
    f. Resistance

VIII. Transformers and Electromagnets

A. Purpose - Electromagnetic devices including the motor and transformer make up the largest group of usuable electrical devices. For this reason it is important that the student study this unit very carefully.

B. Assignment -
1. Read text and references.
2. Answer questions.

C. Reading -
1. Text pages 73-84, 159-173.
2. Basic Electricity - Abraham Marcus, Pages 66-72, 327-344.
3. Understanding Electricity & Electronics - Buban & Schmitt, pages 170-188.
4. Electricity & Electronics Basic - Steinberg & Ford, pages 25-31, 109-125.

D. Questions -
1. What is electromagnetic induction?
2. What determines the strength of an electromagnet?
3. What are the core losses?
4. What effect does the number of turns of a transformer have on the voltage?
5. What is meant by voltage and current transformers?
6. What is a magnetic amplifier?
7. What is a solenoid?
8. What purpose does the core serve in a transformer?
9. What is a relay?
10. Define or describe:
    a. Linkage
    b. Center Tap
    c. Primary
    d. Hystersis
    e. Mutual Induction
    f. Permeability
    g. Gilbert
    h. Maxwell
    i. Saturation
    j. Ohm's law for magnetic circuits.

IX. Motor & Generators

A. Purpose - This is not intended to teach the student motor winding but to give an understanding of A.C.-D.C. motors and generators their types, uses, maintenance and trouble shooting.

B. Assignment -
1. Read text and references.
2. Answer questions.
3. Make a chart of the types of A.C & D.C. motors.

C. Reading -
1. Text pages 174-205.
2. Basic Electricity-Abraham Marcus, pages 178-207, 346-391.
3. Understanding Electricity & Electronics-Buban & Schmitt, pages 218-228, 274-282.

D. Questions -
1. What large advantage does a D.C. motor have over an A.C. type?
2. Write a description of the production of alternating current.
3. How does a commutator work?
4. Why is polyphase A.C. better than single phase?
5. List four types of single phase starting devices.
6. Describe the functioning of an induction motor.
7. Describe the functioning of a synchronous motor.
8. What is pole shading?
9. What are the characteristics of a series D.C. motor?
10. What are the characteristics of a shunt D.C. motor?
11. What is an alternator?
12. Define the following:
    a. Slip ring
    b. Stator
    c. Rotor
    d. Armature
    e. Field
    f. Pole
    g. Squirrel Cage
    h. Laminated
    i. Synchro
    j. Interpole

X. Application of Electricity

A. Purpose - In this unit the student will explore some of the many applications of electrical power. This should help give some insight into the almost infinite possibilities in the field of electricity as a vocation.

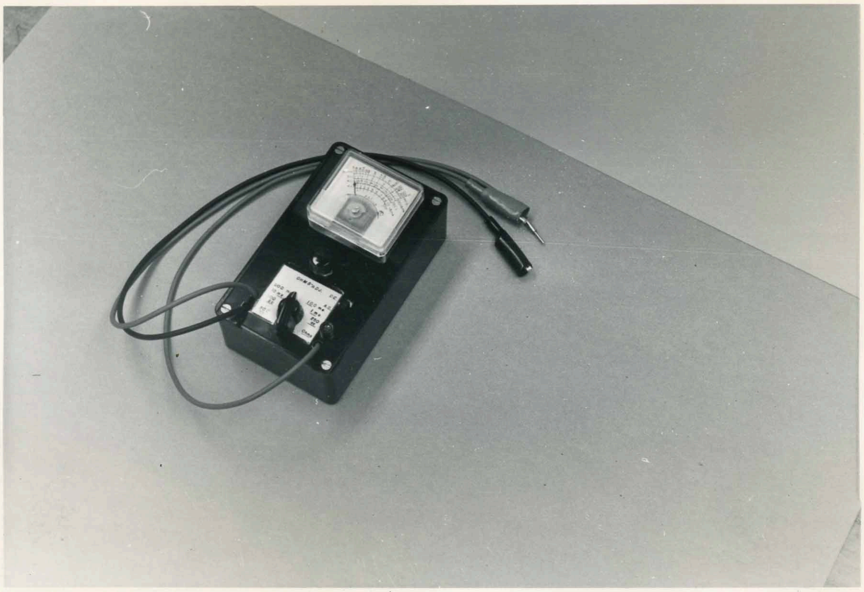
B. Assignment -
1. Read text and references.
2. Answer questions.
3. Write a three page paper on some specific application of electricity.

C. Reading -
1. Text pages 232-252, 255-261, 262-269.
2. Basic Electricity - Abraham Marcus, Pages 254-274, 276-294, 302-309.
3. Electricity & Electronics Basic - Steinberg & Ford, Pages 1-15.

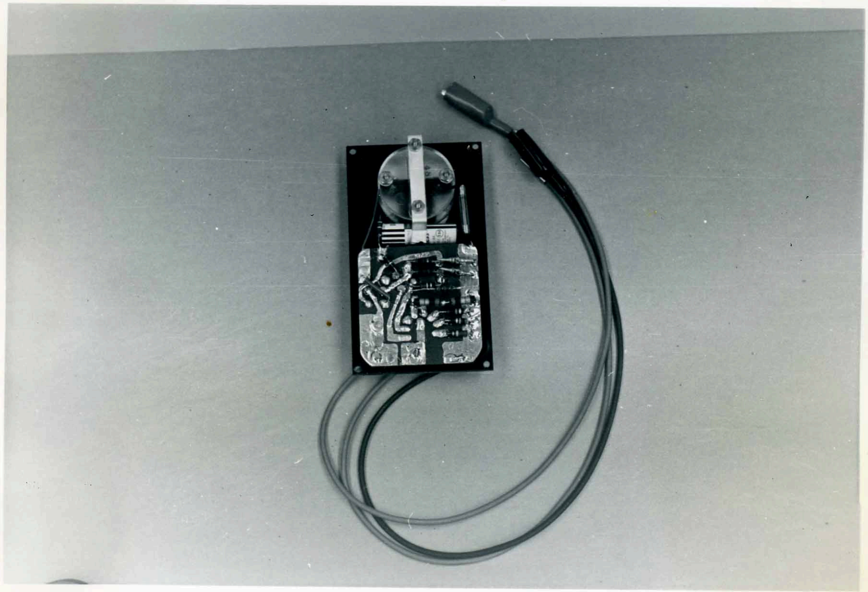
D. Questions -
1. List ten devices working on electro magnetic principles.
2. List ten devices working on electro chemical principles.
3. List ten devices working on the combined principles of electricity and heat.
4. List ten devices working on the combined principles of electricity and light.
5. List six practical uses of static electricity.

APPENDIX G

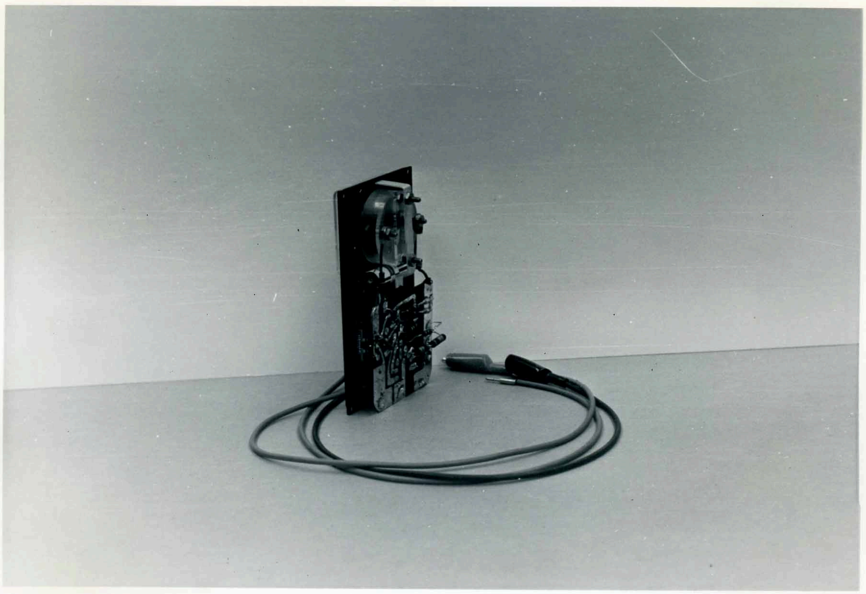
PICTURES OF THE V. O. M. PROJECT



MAY 1965



MAY 1965

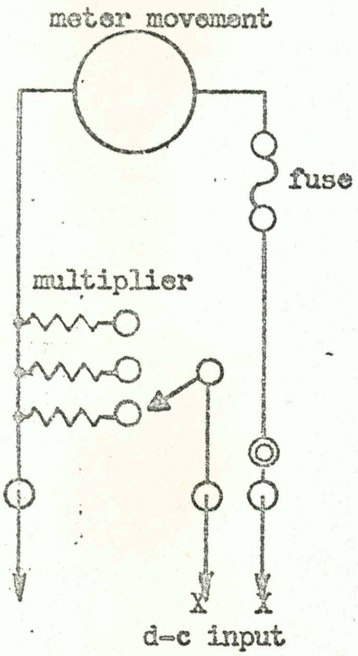


MAY 1965

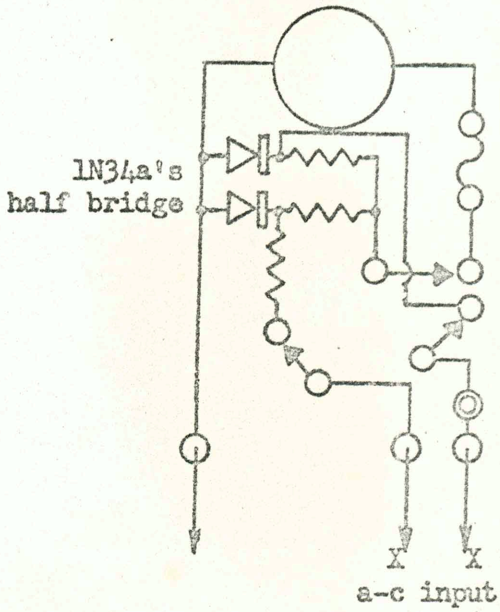
APPENDIX H

PROJECT INFORMATION SHEETS GIVEN TO STUDENTS

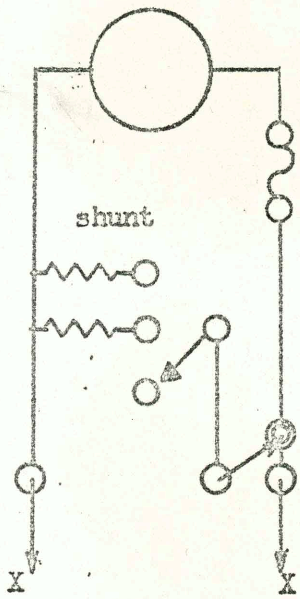
BREAKDOWN OF MULTIMETER CIRCUITS



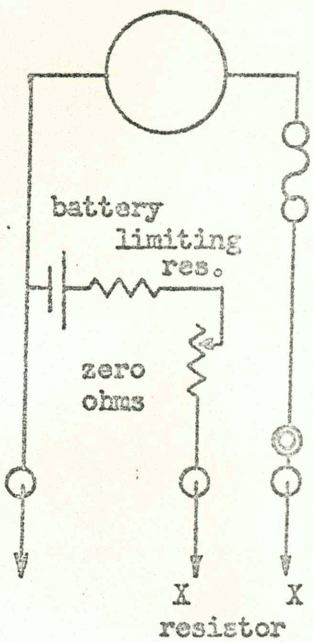
d-c voltmeter



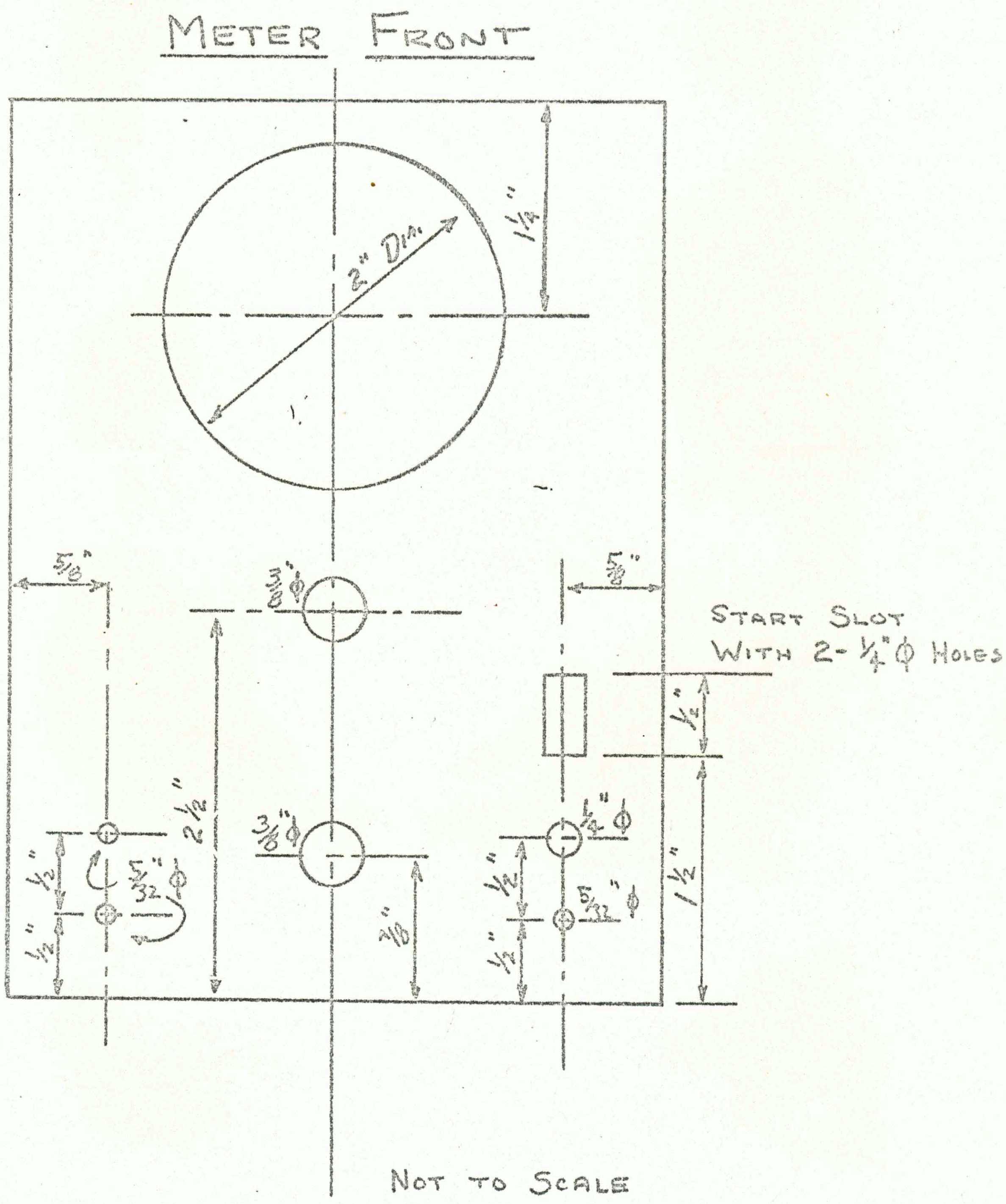
a-c voltmeter



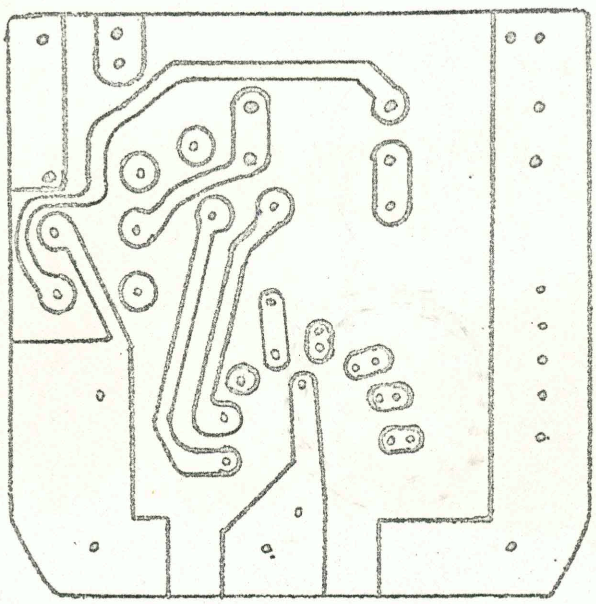
d-c milliammeter



ohmmeter

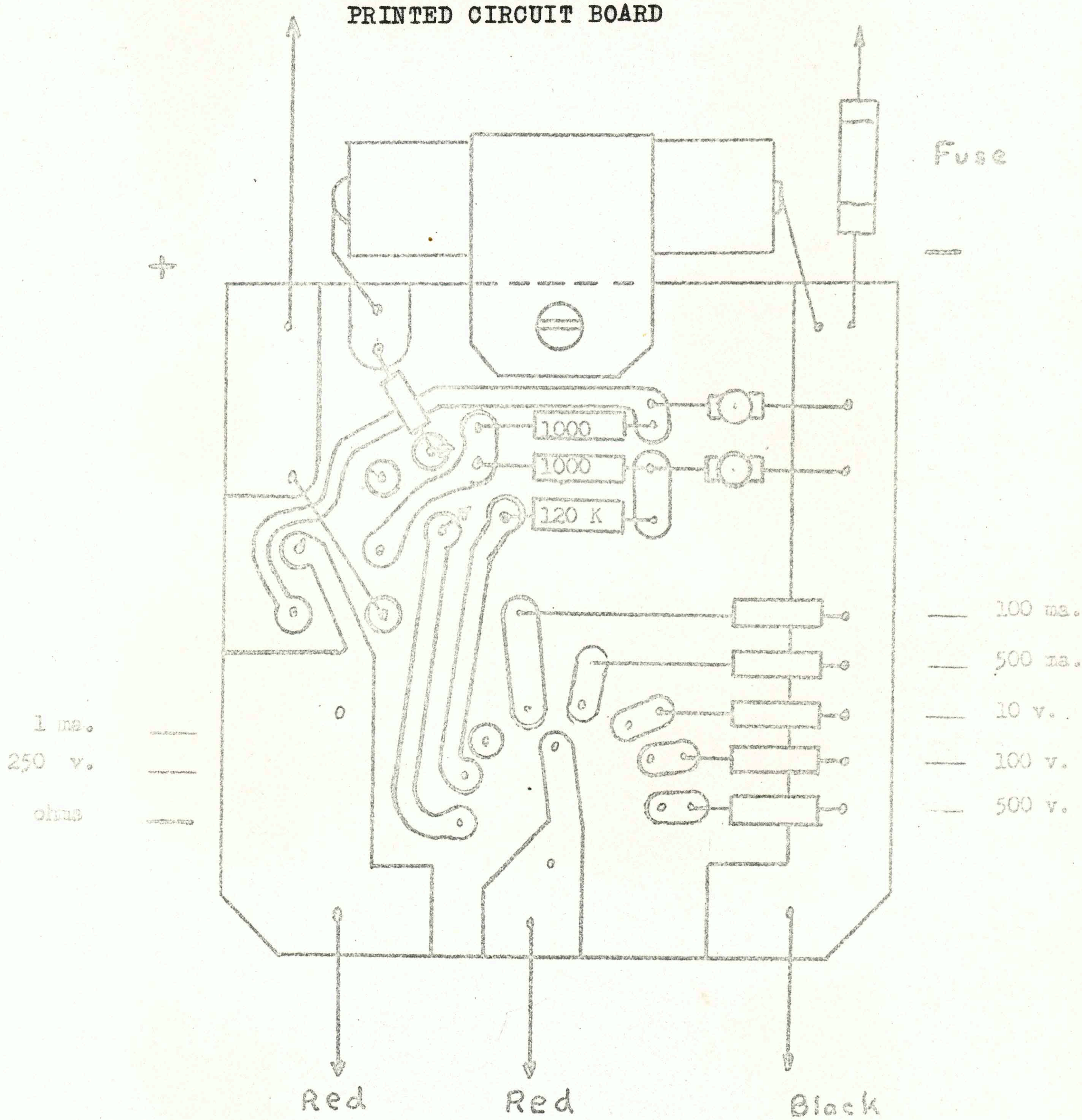

METER FRONT
2" DIA.
1 1/4"
5/8"
5/8"
3/8" φ
START SLOT
WITH 2- 1/4" φ HOLES
1/4"
2 1/2"
3/8" φ
1/4" φ
1/2"
5/32" φ
1/2"
7/8
1 1/2"
NOT TO SCALE

PRINTED CIRCUIT BOARD



PARTS PLACEMENT ON

PRINTED CIRCUIT BOARD



A LISTING OF METER PARTS AND PRICES

ITEM	DESCRIPTION	PRICE BOUGHT FROM SCHOOL	SUPPLY COMPANY	RETAIL PRICE
Battery	1.5 volt		B-A 3264802	.13
Case, (plastic)	6 1/4 x 3 3/4 x 2	.44	Allied-87p885	.66
Case panel		.36	" -87P887	.48
2-Diodes	1N34A	.30	B-A 44B21 30 cents each	.60
Fuse	1/4 amp.	.00	B-A 12A1113	.08
2-Knobs	1 1/4 pointer 11/16 round		" 12A45 " 12A1236	.09 .08
Meter Movement	1 ma. F.S.	4.25		
Meter probes				
Meter scale		.30		
Potentiometer	0-500 Ohm	.22	" 1414B303 500 ohm.	1.14
1-P. C. Board	3 x 3	.26	" 29A107	.26
9-Resistors		.12	" page 67 Cat. No. 651	.12
Socket (pin)	tip jack 1/4 dia.	.05	Allied 39A169	.13
Switch (slide)	DPDT	.10	B-A18B802	.15
Switch (rotory)	1 pole 8 position	.42	" 18D105	.49

Construction materials such as solder, screws, and etc. are not included.

	TOTAL	7.13		8.96

APPENDIX I

EVALUATION INSTRUMENT

BASIC ELECTRICITY TEST

This test is designed to give an indication of your present knowledge of basic electricity. It is important that you try to answer all the questions. Wrong answers will not be counted against you. You will be given the entire period for the test, however, it will be necessary for you to not spend excessive time on any one question until you have completed the test.

If you complete the test before the end of the period, return to the questions of which you were uncertain.

You are not intended to answer all the questions correctly, but it is very important that you do the best you can.

* To avoid possible confusion, all questions dealing with current have reference to electron current flow.

In answering the following questions, pick the response that you think is most correct. Each question has only one correct response.

Answer question number one and put your answer on the answer sheet.

1. A device often used as a portable source of electric energy is a/an: a. capacitor b. battery c. coil d. switch

Since a device often used as a portable source of electric energy is a battery, you should have made a mark between the two vertical lines in the second or "b" column, in the space provided for the answer to question number 1.

Answer question two and record your choice on the answer sheet.

2. Electricity can be used for: a. heat b. light c. power d. all of these

Electricity can be used for heat, light, and power. The correct answer is therefore "all of these." You should have placed a mark between the vertical lines in the fourth or "d" column in the space for answer number 2.

Do not turn the page until told to do so.

____ 3. The type of electricity that causes lightning is: a. sine wave b. current c. static d. direct current

____ 4. The type of electrical circuit having more than one current branch is the: a. parallel circuit b. series circuit c. neither of these d. both of these

____ 5. The instrument most commonly used to indicate electrical wave-form is: a. a hot-wire meter b. an oscilloscope c. stroboscope d. a super-regenerative detector

____ 6. A negative charge is the result of: a. the surplus of electrons b. a deficiency of electrons c. a surplus of protons d. pressure devices

____ 7. With reference to the resistor color code, the color red represents the number: a. 9 b. 2 c. 7 d. 4

____ 8. A charged atom is called an: a. ion b. positron c. electrolite d. reactance value

____ 9. Meter movements used to measure voltage are evaluated according to: a. their ohms per volt characteristic b. their current requirements for full scale deflection c. both of these d. neither of these

____10. The unit for electrical quantity is the: a. coulomb b. volt c. watt d. farad

____11. Which of the following indicate the number of degrees in an electrical cycle: a. 60 b. 120 c. 180 d. 360

____12. Which of the following is the main determiner of a good electrical conductor? a. the materials electron structure b. the length of the material c. the materials molecular weight d. the ability of the material to become a magnet

____13. Which of the following <u>is not</u> a means of removing magnetism from a magnetic material? a. physical shock b. placing the magnet in a strong magnetic field of opposite polarity c. exposing the magnet to extremely cold temperatures d. heat

____14. The frequency of a signal can be determined accurately by using which of the following? a. an oscilloscope b. a V.T.V.M and a signal tracer c. an oscilloscope and a variable signal generator together d. a stroboscope

____15. The total current flow in figure 1 is: a. 50 amps. b. 1 amp. c. 5 amps d. 100 amps

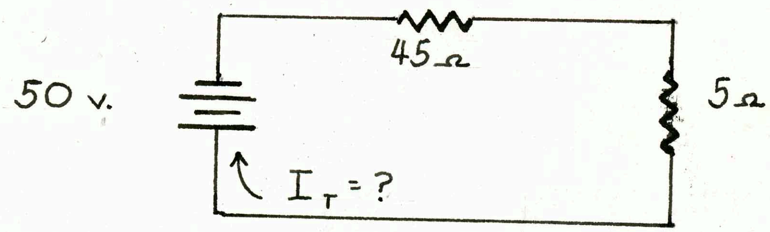


Fig. 1

____16. Identically charged particles: a. attract each other b. will always repel each other c. sometimes attract each other d. may either attract or repel each other

____17. Electricity was discovered: a. by Thomas Edison b. during the time of Benjamin Franklin c. by the General Electric Company d. hundreds of years ago

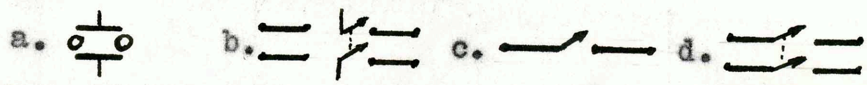
____18. A capacitor is a device which can be used to store: a. magnetism b. neutrons c. alternating current d. electrons

____19. The structural change of a non-magnetized material to a magnetized material can best be expressed in terms of: a. domain action b. a change in the number of electrons c. a change in atomic molecular weight d. proton action

____20. The negative particles with an atom are called: a. neutrons b. protons c. ions d. electrons

____21. A device which is commonly used to open and close a circuit: a. is a rectifier b. a capacitor c. a resistive fader d. a switch

____22. A double-pole-single-through switch is represented by which of the following?



____23. Which of the following factors in a circuit cause the current to lead the voltage? a. inductance b. impedance c. reluctance d. capacitance

____24. Which of the following rules <u>does not</u> apply to magnetic action? a. magnetic lines of force travel from north to south b. magnetic lines of force will form closed loops c. magnetic lines of force enter a magnet at the north pole d. magnetic lines of force will not cross

____25. The voltage applied to the circuit in figure 2 is:
a. 25 volts b. 50 volts c. 100 volts d. 250 volts

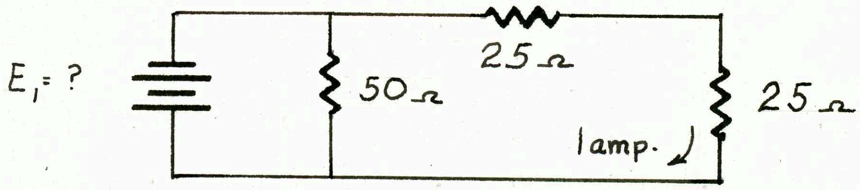


Fig 2

____26. In the resistor color code, the color green indicates which of the following numbers: a. 8 b. 5 c. 3 d. 6

____27. The flow of electrons in a conductor is referred to as: a. induction b. permeability c. current d. all of these

____28. The total opposition to current flow in a circuit is: a. reactance b. reluctance c. impedance d. counter E.M.F.

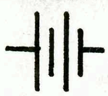
____29. A coil, when operating in a circuit, has the ability to: a. increase pulsating voltage b. rectify A.C. voltage c. store a magnetic field d. all of these

____30. In a magnetic field, lines of force travel from the: a. south pole to north pole b. north pole to south pole c. from north geographic pole to south geographic pole d. none of these

____31. A material in which electrons move easily is called: a. a transducer b. a circuit c. a battery d. a conductor

____32. The type of electricity used in the production of sandpaper is: a. pulsating D.C. b. static c. high voltage A.C. d. electromagnetic D.C.

____33. Which of the following remains most nearly equal on both sides of a transformer? a. voltage b. electrical power c. current d. all of these

____34. The symbol  represents: a. a battery with six cells b. a three phase rectifier c. three batteries d. a three cell battery

____35. Which of the following is a natural magnetic material? a. alnico b. magnetite c. iron d. nickel

____36. The power dissipated by R_1 if figure 3 is: a. 10 watts b. 5 watts c. 5 amps d. 10 volts

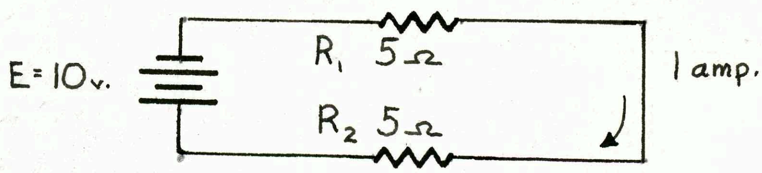
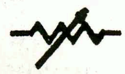


Fig. 3

____37. Which of the following is given credit for the expression (E=IR): a. Gustav R. Kirchhoff b. George Simon Ohm c. James Watt d. Guglielmo Marconi

____38. Which of the following is a variable inductor?

a.  b.  c.  d. 

____39. The ability of a magnet to maintain its magnetism is referred to as: a. retentivity b. permeability c. magnetic strength d. magnetic stability

____40. Which of the following is given consideration when discussing current flow? a. electrons g. amperes c. coulombs d. all of these

____41. Heating elements are commonly made of: a. Chromium b. Copper c. Nichrome d. Nickel

____42. The most common meter movement used today is the: a. hot-wire b. d'Arsonval c. plunger vane d. V.O.M.

____43. Which of the following will least effect the magnetic ability of a coil? a. amount of current flow within the coil b. the number of coil windings c. the core material d. the temperature of the core

____44. Paper and mica are excellent: a. conductors b. inductors c. capacitors d. insulators

____45. In order to have current flow between two terminals in a circuit, there must be: a. capacitance in the circuit b. inductance in the circuit c. an equal amount of electrons at each terminal d. a difference in potential

____46. Voltmeters can indicate various ranges of voltage by addingto the meter circuit: a. capacitors b. rectifiers c. dropping resistors d. dropping inductors

____47. Which of the following represents a transistor?

a.  b.  c.  d. 

____48. The total voltage produced from batteries of equal value connected in parallel: a. is equal to the total of the battery voltages b. is equal to the voltage produced by one battery c. increases as the current increases d. will vary directly according to the resistance placed across them

____49. The value of I_4 in figure 4 is: a. 5 amps b. 2.5 amps c. 3 amps d. none of these

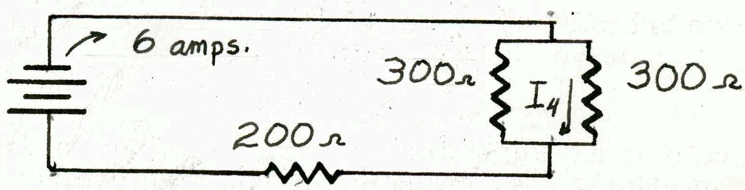
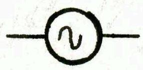


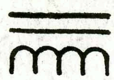
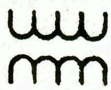
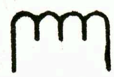
Fig. 4

____50. The symbol  represents: a. a sine wave

b. an oscilloscope c. an A.C.generator d. an A.C. motor

____51. If a portion of a circuit is "shorted": a. it has no impedance b. it has infinite resistance c. it has very high voltage across it d. it is similar to an open switch

____52. Of the following, which has the greatest potential for creating a strong magnetic field?

a.  b.  c.  d. 

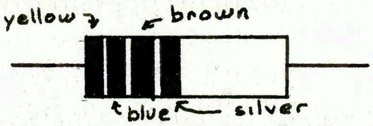
____53. The unit of electrical resistance is the: a. coulomb b. ampere c. ohm d. reluctance factor

____54. Parallax error often results when: a. measuring parallel resistors b. reading a meter scale c. using Ohm's law d. listening for a change in sound with the human ear

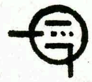
____55. When being stored, the V.O.M. should have its range selector switch turned to: a. low votage D.C. b. high voltage D.C. c. 10 ma A.C. d. high voltage A.C.

____56. The best conductor of electricity is: a. silver b. iron c. copper d. mica

____57. Using the resistor color code what is the number represented on the resistor: a. 3500 b. 460 c. 27,000 d. 68



____58. Which of the following represents a device which can be used to rectify A.C.?

a.  b.  c.  d. all of these

____59. Which of the following is not a prime factor in determining the resistance of a wire: a. insulation b. diameter c. material d. temperature

____60. The meter which has mid-scale position, representing zero current, when isolated from current flow: a. is used to measure negative and positive resistance b. measures mostly polarity of magnets c. is a galvanometer d. uses a solenoid-type meter movement

____61. What type of meter is represented if figure 5? a. an ammeter b. a volt meter c. a watt meter d. a phase shift meter

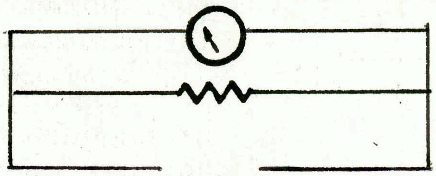


Fig. 5

____62. Two or more cells make up a: a. circuit b. inductor c. battery d. capacitive reactor

____63. Graphic vectors are frequently used to determine: a. impedance b. phase angle c. inductive and capacitive reactance d. all of these

____64. The path through which electrons can flow from one terminal of the generator to the other is called? a. a ground wire b. an insulator c. the path of force d. a circuit

____65. In pure inductive circuits voltage has what time relationship with current? a. the voltage leads the current b. the current leads the voltage c. the voltage is usually less than 60 degrees ahead of the current d. the current and voltage are together

____66. When an electron escapes from the attraction of its core or nucleus, it is said to be: a. a static electron b. a free electron c. a positive electron d. a neutral electron

____67. Eddy currents in a core are most commonly reduced via: a. putting plastic around the core b. placing the core in a vacuum c. laminating the core d. making the core more permeable

____68. The instrument that is connected in series with the circuit being tested is the: a. ammeter b. oscilloscope d. d'Arsonval d. all of these

____69. What type of meter is represented in figure 6? a. a volt meter b. a watt meter c. an ohm meter d. a frequency meter

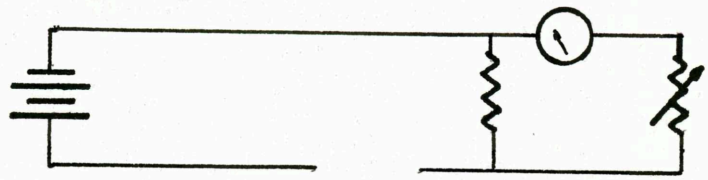


Fig. 6

____70. The meter movement that deflects 1/2 scale while conducting 5 ma: a. is a 20 ma. meter b. would require a shunt to measure 10 ma. c. is of little value due to its low current capacity d. none of these

____71. The main purpose of the "three wire" system for small electric machine tools is: a. the supply more power b. to reduce danger of electrical shock c. to reduce the danger of overloading the circuit d. to prolong the life of the machine

____72. Which of the following will produce an E.M.F. when mechanical pressure is applied? a. a capacitor b. quartz crystals c. a coil d. a battery

____73. Which of the following is associated with electrical pressure? a. volts b. counter electromotive force c. a generator d. all of these

____74. Which of the following can be used to vary resistance in a circuit? a. a rheostat b. a potentiometer c. a voltage regulator tube d. all of these

____75. The unit for magnetic flux density is: a. Maxwell b. Oersted c. Gauss d. Henry

____76. Voltmeters are connected to the circuit: a. in parallel b. in series c. parallel if measuring positive voltage and series if negative d. none of these

____77. The component that must be added to a D.C. meter circuit for it to indicate A.C. voltage is: a. a shunt b. a transformer c. a rectifier d. a battery

____78. Most meters are primarily: a. an ohmeter b. an ammeter c. a volt meter d. none of these

____79. The value of E_1 in figure 7 is: a. 200 volts b. 400 volts c. 300 volts d. 700 volts

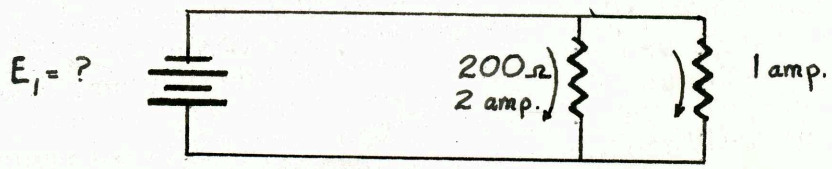


Fig. 7

____80. Paramagnetic materials: a. will not form magnets b. will not form the best magnets c. have less permeability than diamagnet materials d. none of these

____81. Magnetic shielding is most practically obtained via: a. a magnetic conductor b. an anti-magnetic field c. wood shielding d. asbestos

____82. At the present time most commercially generated electricity is: a. D.C. b. 60 cycle D.C. c. rectified A.C. d. 60 cycle A.C.

____83. The time difference between two electrical wave forms can be referred to as the: a. wave angle b. phase angle c. electrical separation d. reactance value

____84. A device commonly used to test electric motor armatures is: a. a growler b. a signal tracer c. an oscilloscope d. a spark tester

____85. Magnetic hysteresis: a. occures in ferromagnetic substances b. is caused by a varying magnetic field c. is a producer of heat d. all of these

____86. The term defining the ease with which magnetic lines of force move within a material is: a. permeability b. conductance c. inductance d. impedance

____87. Opposition to the production of a magnetic field is: a. impedance b. ohms c. reactance d. reluctance

____88. The circuit in fig. 8 is most generally used for:
a. measuring volts and ohms. b. measuring current
c. determining the resistance of a meter movement
d. the measuring of electrical power

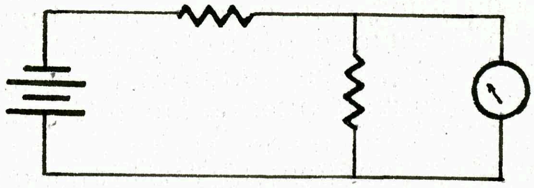
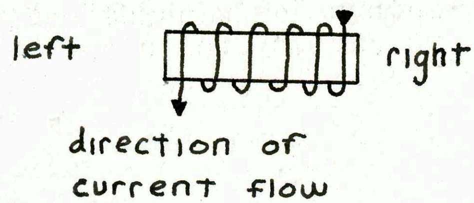


Fig. 8

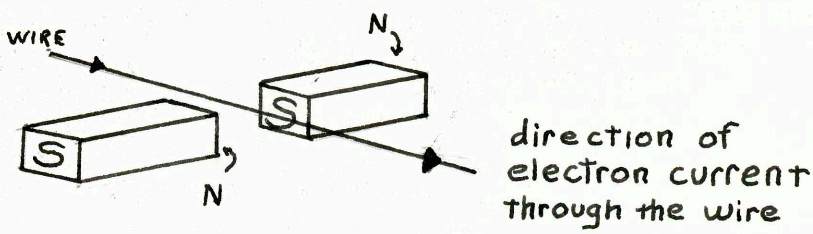
____89. Which of the following modifications should be made in a meter circuit using a 10 ohm, 50 ma. meter movement, if full scale deflection is to represent 100 volts D.C.? a. 20,000,000 ohm shunt b. a 2 ohm dropping resistor c. a 2,000 ohm dropping resister d. a .02 ohm shunt

____90. If the above meter were used to measure 10 amperes, assuming that the answer to question 89 has been removed from the circuit which of the following additions would need to be made? a. a .05 ohm shunt b. a 10,000 ohm shunt c. a 10,000 ohm dropping resistor d. a 5 ohm dropping resistor

____91. If electron current is flowing through the coil in the direction shown, which end of the coil forms a north pole? a. the right end b. the left end c. neither end d. the poles will oscillate due to counter E.M.F.



____92. Assuming electron current flow, in which direction will the wire be deflected? a. toward the south pole b. in an upward direction c. in a downward direction d. toward the north pole



APPENDIX J

DAILY OBSERVATION SHEET

DAILY RECORD

Class: Basic Electricity (140), 8:30 M-F   Date:__________

Lecture Time = __________ Min.

Experiment Time = __________ Min.

Project Time = __________ Min.

Means of Instruction

1. Lecture and Discussion:
2. Demonstrations:
3. Overlays:
4. Films:
5. Assignments:
6. Others:

Material Presented

1. Definitions:
2. Terms:
3. Theory:
4. Laws:
5. Operations:
6. Practical Applications:
7. Other Related Information:

Assignments Given

1. Reading:
2. Problems:
3. Special:

Observations and Comments

APPENDIX K

ANALYSIS OF DATA

TABLE V

TEST SCORES AND POINTS GAINED ON THE ELECTRICITY-ELECTRONICS TEST BY EACH STUDENT

Group A					Group B				
Student	L.T.I.T.	E_1	E_2	Gain	Student	L.T.I.T	E_1	E_2	Gain
1a	56	69	82	17	1b	54	54	60	6
2a	50	42	58	16	2b	62	52	66	14
3a	50	35	64	29	3b	51	33	52	19
4a	52	33	46	13	4b	43	37	43	6
5a	48	52	68	16	5b	54	45	56	11
6a	49	39	62	23	6b	59	42	77	35
7a	45	35	40	5	6b	63	46	61	15
8a	57	31	51	20	8b	64	78	84	6
9a	54	45	71	26	9b	55	52	67	15
10a	70	45	56	11	10b	55	53	57	14
11a	47	53	67	14	11b	45	48	64	16
12a	53	61	65	4	12b	45	58	81	23
13a	45	42	62	20	13b	61	56	62	6
14a	48	45	61	16					
15a	52	41	56	15					
Means	51.7	44.6	60.6	16.3		54.7	50.4	64.6	14.2

L. T. I. T = Lorge-Thorndike Intelligence Test
E_1 = Electricity-Electronics Pretest
E_2 = Electricity-Electronics Posttest
G = Gain

TABLE VI

MEANS OF STUDENT'S PRETEST AND POSTTEST SCORES ON THE ELECTRICITY-ELECTRONICS TEST ON THE DIFFERENCE IN PRETEST AND POSTTEST MEANS

	Pretest	σ	Posttest	σ	diff. in pretest and posttest means
Group A	44.6	10.2	60.6	9.9	16.3
Group A	50.4	10.9	64.6	10.3	14.2

TABLE VII

ANALYSIS OF VARIANCE OF INITIAL LEARNING SCORES OF SUBJECTS USED IN THE FINAL ANALYSIS OF TREATMENT

Source	d.f.	ss_X	Means Sq.	F.
Between Groups	1	112	112	.96
Within Groups	26	3029	116	
Total	27	3141		

F at the .05 level = 4.22
F at the .01 level = 7.72

TABLE VIII

NUMBER OF STUDENTS WHO MISSED EACH QUESTION ON THE ELECTRICITY-ELECTRONICS PRETEST AND POSTTEST

	Group A			Group B		
Quest. No.	Pretest Score	Posttest Score	Dif.	Pretest Score	Posttest Score	Dif.
3	3	1	2	0	0	0
4	6	2	4	4	0	4
5	0	0	0	0	0	0
6	8	4	4	4	1	3
7	7	4	3	8	9	-1
8	3	2	1	0	0	0
9	10	3	7	9	8	1
10	10	6	4	10	7	3
11	10	8	2	9	4	5
12	4	2	2	0	0	0
13	6	0	6	4	0	4
14	9	9	0	9	3	6
15	3	2	1	6	3	3
16	1	1	0	0	0	0
17	2	7	-5	3	3	0
18	5	5	0	3	3	0

(Table Continues on Next Page

Note: [a]N for group A = 15
N for group B = 13

[b]1 and 2 were sample questions

TABLE VIII
(continued)

NUMBER OF STUDENTS WHO MISSED EACH QUESTION
ON THE ELECTRICITY-ELECTRONICS PRETEST
AND POSTTEST

	Group A			Group B		
Quest. No.	Pretest Score	Posttest Score	Dif.	Pretest Score	Posttest Score	Dif.
19	7	2	5	5	0	5
20	8	4	4	1	0	1
21	0	0	0	0	0	0
22	9	11	-2	6	5	1
23	11	10	1	13	11	2
24	6	5	1	2	0	2
25	9	14	-5	8	6	2
26	12	10	2	8	5	3
27	7	4	3	5	4	1
28	11	11	0	7	10	3
29	11	8	3	10	8	2
30	7	3	4	2	1	1
31	0	0	0	1	1	0
32	10	6	4	10	5	5
33	9	11	-2	8	5	3
34	5	5	0	4	1	3
35	1	1	0	1	0	1
36	11	6	5	8	6	2

(Table Continues on Next Page)

TABLE VIII
(continued)

NUMBER OF STUDENTS WHO MISSED EACH QUESTION
ON THE ELECTRICITY-ELECTRONICS PRETEST
AND POSTTEST

	Group A			Group B		
Quest. No.	Pretest Score	Posttest Score	Dif.	Pretest Score	Posttest Score	Dif.
37	8	0	8	3	1	2
38	9	6	3	4	3	1
39	5	9	-4	5	5	0
40	4	3	1	4	4	0
41	6	8	-2	6	2	4
42	13	1	12	10	2	8
43	7	1	6	1	1	0
44	5	5	0	3	0	3
45	4	1	3	5	1	4
46	8	2	6	7	1	6
47	6	4	2	6	4	2
48	5	5	0	5	4	1
49	12	2	10	10	12	-2
50	9	6	3	8	2	6
51	14	10	2	10	6	4
52	10	12	-2	7	2	5
53	3	0	3	0	0	0
54	11	1	10	11	7	4

(Table Continues on Next Page)

TABLE VIII
(continued)

NUMBER OF STUDENTS WHO MISSED EACH QUESTION ON THE ELECTRICITY-ELECTRONICS PRETEST AND POSTTEST

	Group A			Group B		
Quest. No.	Pretest Score	Posttest Score	Dif.	Pretest Score	Posttest Score	Dif.
55	14	4	10	8	6	2
56	6	2	4	3	1	2
57	9	8	1	10	10	0
58	10	13	-3	9	8	1
59	2	0	2	1	1	0
60	8	8	0	6	6	0
61	12	7	5	9	3	6
62	5	1	4	4	1	3
63	7	5	2	7	9	-2
64	7	3	4	4	1	3
65	12	11	1	11	10	1
66	3	1	2	5	0	5
67	9	11	-2	3	3	0
68	4	1	3	6	2	4
69	7	6	1	3	7	-4
70	10	1	9	4	1	3
71	0	1	-1	0	0	0

(Table Continues on Next Page)

TABLE VIII
(continued)

NUMBER OF STUDENTS WHO MISSED EACH QUESTION ON THE ELECTRICITY-ELECTRONICS PRETEST AND POSTTEST

	Group A			Group B		
Quest. No.	Pretest Score	Posttest Score	Dif.	Pretest Score	Posttest Score	Dif.
72	6	1	5	6	0	6
73	8	8	0	11	8	3
74	11	5	6	11	7	4
75	11	13	-2	10	10	0
76	5	0	5	7	2	5
77	7	0	7	5	0	5
78	9	0	9	8	5	3
79	7	9	-2	12	6	6
80	13	9	4	9	5	4
81	10	6	4	8	0	8
82	7	4	3	4	0	4
83	7	3	4	4	0	4
84	3	3	0	4	3	1
85	12	8	4	8	4	1
86	13	7	6	8	2	6
87	11	4	7	8	0	8
88	7	11	-4	9	10	-1
89	10	2	8	9	5	4
90	13	6	7	10	6	4
91	7	5	2	8	5	3