INSTRUCTOR-WRITTEN PHYSICS LABORATORY EXPERIMENTS USING THE INDUCTIVE METHOD

A Thesis
Presented to
the Graduate Council
Kansas State Teachers College
of Emporia, Kansas

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Richard W. Burkey
July 1958

Approved for the Major Department

Approved for the Graduate Council

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. S. Winston Cram for his help and guidance in writing this thesis. Appreciation also goes to Dr. Weldon N. Baker and Mr. Glenn H. Crumb for their constructive criticisms of this thesis; and to the students of the Northern Heights High School physics class of 1958 who contributed to this study.

TABLE OF CONTENTS

CHAPTER I

THE PROBLEM

The desire to enhance the impact of the high school physics upon the pupils through the laboratory experience was created while teaching this course for the first time. The laboratory experience seemed to lack the impetus to arouse within the pupils the interest needed to give them the necessary motivation and understanding.

Several references[1] and lectures given by science teachers made it evident that the need for improved laboratory procedure was a national problem.

I. STATEMENT OF THE PROBLEM

The purpose of this thesis is to provide some laboratory experiences in physics which will (1) develop a functional understanding of the principles, facts and concepts; (2) create interest in the physics course; (3) incorporate

---

[1]George Greisen Mallinson, "The Role of Physics in the Emerging High School," School Science and Mathematics, 55:211-16, March, 1955; Paul F. Brandwein, "Obstacles to Increased Physics Enrollment," American Journal of Physics, 23:537-41, November, 1955; Richard M. Sutton, "The College Teachers look at High School Science," The Science Teacher, 22:184, May, 1956; Hayn Kruglak, "The Effect of High School Physics and College Laboratory Instruction on Achievement in College Physics," Science Education, 39:219-22, April, 1955; Physical Science Study, "Building a New Structure," The Science Teacher, 24:315, November, 1957; Ray C. Maul, "Science Teachers for Tomorrow," The Science Teacher, 20: 173-5, September, 1953.

more of the objectives of science and general education than found in traditional manuals; (4) increase the skill in communicating ideas intelligently.

II. SCOPE OF THE PROBLEM

In this thesis only a small portion of the vast problem of physics instruction was selected for study and a possible solution. The portion of the physics problem selected was the improvement of physics experiments.

III. IMPORTANCE OF THE PROBLEM

In the period 1945-1955 there was a rapid decline in the number of high school students taking physics courses.[2] Subsequent events have started the efforts to improve the course of secondary physics in order to make it more meaningful and appealing.

A large percentage of these students "are a 'captive audience,' in the sense that they are required to pass the course to get into college."[3] This decline in enrollment and the fact that most students take high school physics because it is required suggests that a reorganization with a change of emphasis within the physics syllabus might be

---

[2]Ray C. Maul, "Is the Science Teacher Shortage a Curriculum Factor?" <u>The Science Teacher</u>, 23:181-3, May, 1956.

[3]Walter C. Michels, "The Teaching of Elementary Physics," <u>Scientific American</u>, 198:30, April, 1958.

desirable.[4]

There is additional evidence which suggests a reorganization of the high school physics course. Since the early years of the twentieth century, the natural sciences have undergone two distinct changes. First, the sciences themselves have grown considerably, both in technique and in depth. Second, the science has become more interwoven with our daily life. Modern man has moved farther from the soil and closer to the laboratory. Whether aware of it or not, he lives out his life in constant association with scientific methods and the benefits of scientific research.

For some time, scientists and educators have been aware that this altered state of affairs is inadequately being met in secondary education. The teaching of science has changed substantially both in content and in technique in the last fifty years. But on the whole, the changes have consisted in additions of new phases of science and alterations of the existing phases. Recently there has been repeated outcries that this bit by bit reconstruction has long since failed in its purpose, and that a complete reorganization of secondary physics is now necessary.[5]

A functional physics laboratory which would create

---

[4] Ibid.

[5] Elbert P. Little, "In These Beginings," The Science Teacher, 24:315, November, 1957.

interest, and stimulate the learning process would be a step towards improving the course. The degree of interest, motivation, and learning in the laboratory is usually developed through the use of a laboratory manual and its method of approach. If a greater degree of interest, motivation, and learning is to be accomplished, the change will have to be in the laboratory manual and the laboratory procedure.

It is a fairly well established belief that students gain more from experiences in which they are participants than from those in which they are only observers.[6]

This favors a laboratory type of experience in which the student is allowed to be an active participant both mentally and physically. By being mentally active does not imply that the student merely follows directions. It implies that the student should have a definite part in such things as planning of the experimental procedure, data sheet, and writing up of his own results and conclusions. The assistance the student needs in planning the experimental procedure and drawing the conclusions could best be provided by means of questions, drawings, and the wording of the experiment which would direct the student's thinking. This seems to point to the need for a laboratory manual employing the inductive method of teaching.

---

[6]Elwood D. Heiss, Ellsworth S. Obourn, and Charles W. Hoffman, Modern Methods and Materials for Teaching Science (New York: The Macmillan Company, 1951), pp. 17-18.

CHAPTER II

THE DEVELOPMENT OF THE EXPERIMENT

I. DEFINITIONS OF TERMS USED

Inductive Method of Teaching.

By inductive teaching is meant progressing from the particular to the general, or more specifically, from the facts to concepts and principles. Inductive teaching is illustrated by having the pupils experiment with simple levers until they are able to arrive at the principle.[7]

Scientific Method.

The scientific method is a pattern of investigation and possible solution to a problem.[8]

Problem-Solving.

Problem-solving may be defined as the process of seeking the answers to questions which cannot be answered by simply reading, remembering, smelling, tasting, looking or listening.[9]

Creative Thinking.

A problem becomes creative thinking when there is added the strictly personal contribution of the 'hunch' or 'guess'. Although based upon experience and facts and tested by logical processes in relation to facts,

---

[7]Nelson B. Henry, editor, "Science Education in American Schools," The Forty-Sixth Yearbook of the National Society for the Study of Education, Part 1 (Chicago: The University of Chicago Press, 1947), p. 49.

[8]Max Black, Critical Thinking (New York: Prentice-Hall, Inc., 1946), pp. 304-5.

[9]Robert W. Frederick, Clarence E. Ragsdale, and Rachel Salisbury, Directing Learning (New York: D. Appleton-Century Company, 1938), p. 46.

> it provides a new principle or relationship that could not have been predicted with accuracy until it appeared.[10]

II. REVIEW OF LITERATURE

There seems to be a real need for an improvement in most of the present laboratory manuals; mainly in the manner of presentation of the material in the manuals.

In order to gain some guiding principles for the formulation of a new type of experiment it was first necessary to discover what the desired objectives of a high school physics laboratory course are. The eleven objectives by The Presidents Commission on Higher Education[11] and The Ten Imperative Educational Needs as stated by The Educational Policies Commission[12] were considered with the question in mind--which of these objectives could be achieved in a high school physics laboratory course. The objectives from the President's Commission on Higher Education[13] which seemed appropriate are the following:

1. To develop for the regulation of one's personal and civic life a code of behavior based on ethical

---

[10] Ibid., p. 463.

[11] "A Report of The President's Commission on Higher Education," Higher Education for American Democracy, Establishing the Goals, Vol. I (New York: Harper and Brothers Publishers, 1948), pp. 50-58.

[12] Educational Planning Commission, Life Adjustment Program (Topeka, Kansas: Kansas State Teachers Association, (Revised March, 1950), p. 15.

[13] Loc. cit.

principles consistent with democratic ideals.

2. To participate actively as an informed and responsible citizen in solving the social, economic, and political problems of one's community, state, and nation.

3. To recognize the interdependence of the different peoples of the world and one's personal responsibility for fostering international understanding and peace.

4. To understand the common phenomena in one's physical environment, to apply habits of scientific thought to both personal and civic problems, and to appreciate the implications of scientific discoveries for human welfare.

5. To understand the ideas of others and to express one's own effectively.

6. To understand and enjoy literature, art, music, and other cultural activities as expressions of personal and social experiences, and to participate to some extent in some form of creative activity.

7. To choose a socially useful and personally satisfying vocation that will permit one to use to the full his particular interests and abilities.

8. To acquire the use of the skills and habits involved in critical and constructive thinking.

Since the daily life of the individual has grown more complex in the last half century there is the need to consider a life adjustment program. The Ten Imperative Education Needs stated by The Educational Policies Commission[14] were considered in order to ascertain which ones were applicable to a physics laboratory course. Those which were found to be applicable are the following:

---

[14] Op. cit., p. 15.

1. All youth need to develop salable skills and those understandings and attitudes that make the worker an intelligent and productive participant in economic life.

2. All youth need to know how to purchase and use goods and services intelligently, understanding both the values received by the consumer and the economic consequences of their acts.

3. All youth need to understand the methods of science, the influence of science on human life, and the main scientific facts concerning the nature of the world and of man.

4. All youth need to be able to use their leisure time well and to budget it wisely, balancing activities that yield satisfactions to the individual with those that are socially useful.

5. All youth need to develop respect for other persons, to grow in their insight into ethical values and principles, and to be able to live and work cooperatively with others.

6. All youth need to grow in their ability to think rationally, to express their thoughts clearly, and to read and listen with understanding.

The committee for the Forty Sixth Yearbook of the National Society for the Study of Education[15] has analyzed the objectives of science instruction. An outline of major objectives are the following:

1. Providing opportunities for growth in the functional understanding of facts.

2. Providing for development of functional concepts.

3. Providing for growth in the functional understanding of principles.

4. Providing opportunity for growth in basic instrumental skills.

---

[15]Henry, op. cit., p. 49.

5. Providing opportunity for growth of skill in the use of elements of scientific method.
6. Providing for growth in the development of scientific attitudes.
7. Providing for growth in the development of appreciations.
8. Providing for growth in the development of interests.

The second step was that of making a study of the present high school physics laboratory course. This consisted of reading and reviewing several laboratory manuals or workbooks[16] with the purpose of discovering the presentation of the material and method of performing the experiment.

A general analysis of the laboratory manuals studied was that all followed very nearly the same pattern of presenting the material. This general pattern consists of the following:

1. Statement of the object of the experiment.

---

[16] Oswald H. Blackwood, Wilmer B. Herron and William C. Kelly, Workbook and Laboratory Manual to accompany High School Physics (New York: Ginn and Company, 1954); L. Paul Elliott, William F. Wilcox and Irving Orfuss, Laboratory Manual and Workbook for Physics (New York: The Macmillan Company, 1958); H. Emmett Brown and Edward C. Schwachtgen, Laboratory Manual Physics: The Story of Energy (Boston: D. C. Heath and Company, 1950); Burns, et al., Activities in Physics (New York: D. Van Nostrand Company, Inc., 1954); Walter L. Ahner, Amsco Workbook and Laboratory Manual in Physics (New York: Amsco School Publications, Inc., 1956); Charles E. Dull, H. Clark Metcalfe, and John E. Williams, Physics Workbook (New York: Henry Holt and Company, Inc., 1955); Baker, Brownlee and Fuller, Laboratory Experiments in Physics (New York: Allyn and Bacon, Inc., 1953).

2. Introduction or discussion of the experiment.
3. Directions for performing the experiment which were very detailed.
4. Data sheet already outlined.
5. Questions about the results, conclusions, and applications of the experiment.

Based upon the objectives, the conclusions drawn from this study were:

1. Nothing is done toward giving the student a chance to increase his skills in the organization of procedure and data.
2. The teaching of problem solving is practically nil.
3. Very few of the experiments permitted the student to express initiative while performing the experiment.
4. The computational experience is provided but so detailed it does not allow the student to think for himself.
5. Very little is done in these experiments to aid the student in learning to draw conclusions.
6. The experiment allows the student to be active physically but not to any great extent mentally.

Although the laboratory manuals studied have many faults, they do meet some of the following objectives:

1. To give the student an opportunity to become familiar with facts and phenomena.

2. To allow the student to obtain skill in the use of scientific instruments.
3. To give the student an opportunity to learn to read and to follow directions.
4. To give the student some computational experience.
5. To allow the student to be active physically.

Certain other objectives were met by some of the experiments but these were the most common and evident objectives in the experiments.

III. GENERAL PLAN OF THE EXPERIMENT

A review of the objectives as submitted by outstanding educational groups and the review of the current high school physics laboratory manuals suggested a new method of presenting the material. After many attempts, a plan was formulated which included seven distinct steps. The steps in this plan are:

1. Present the objectives in such a manner as to give the student direction in formulating his procedure and collecting the necessary data.
2. Present a clear explanation of the theory to motivate interest and further study.
3. Check the student's thinking, progress, and learning by the use of discussion questions.
4. Provide statements which will aid the student in performing the experiment, formulating the procedure,

and organizing the data sheet.

5. Provide space for the student's procedure, data sheet, and calculations, to allow for his own approach to the experiment.
6. Provide questions which aid the student to draw conclusions and to check his learning process.
7. Provide space for a written conclusion and thus allow the student to communicate his information to others.

The experiments, written according to this plan, were used in the Northern Heights High School physics class to determine if the material presented was in a suitable form and not too difficult for a high school student. The experiments in this thesis were not altered in form after actual laboratory usage.

IV. ORGANIZATION OF THE EXPERIMENT

The general organization of the experiments is similar to the organization of the experiments used in traditional laboratory manuals; however there is a great difference in the manner in which each section is utilized. The experiments have been written according to the following plan: (1) objectives of the experiment; (2) theory and explanation; (3) further references; (4) questions to check the learning process; (5) materials and equipment; (6) drawing; (7) operation of the apparatus; (8) points to observe in setting up and operating the apparatus; (9) procedure; (10) data sheet and calculations; (11) questions and conclusions. The following are statements that clarify each part and served as a criteria in developing each section of the experiment.

Objectives of the experiment. The objectives of the experiment are clear and brief statements which will aid and direct the student's thinking toward the objectives sought in the experiment. Also the objectives aid the student in collecting the necessary data to perform the experiment.

Theory and explanation. The theory and explanation is designed in such a manner as to give the student statements of the facts, principles, concepts, and explicit directions. It is also designed to create interest, to motivate further study, and to aid the student in formulating the procedure and planning a data sheet.

Further references. These references will provide the student with additional factual information.

Questions. This section of questions is designed to check the student's knowledge of the material presented in the theory and explanation.

Materials and equipment. This is a list of suggested materials and equipment to enable the student to perform the experiment. It is understood that in many cases different laboratories will wish to design their own equipment, for most of the equipment can be made in the laboratory or obtained locally. The cost of the materials and equipment has been kept to a minimum.

Drawing. The drawing is a sketch which will enable the student to set up the apparatus and suggest to him a method or an idea of a method by which he can conduct the experiment. The drawing gives further suggestions for formulating the method of procedure and information on the usage of the apparatus.

Operation of the apparatus. The purpose of this section is to present an explanation of the principles involved in operating the apparatus. This section will also aid the student to develop a method of procedure for the experiment.

Points to observe in setting up and in operating the apparatus. This section consists of pertinent statements which should definitely suggest ideas to aid the student in setting up and in operating the apparatus.

Procedure. The student is to plan the method of procedure by which he can obtain the data necessary "to discover" the principles or concepts set forth in the objectives.

The suggestions in the preceding parts of the experiment will assist the student in planning the method of procedure and in collecting the necessary data. In the case of the slower students the instructor will need to lend assistance in planning the method of procedure.

The student's method of procedure is to be checked by the instructor before he begins any actual experimentation. This will indicate to the instructor the student's knowledge of the experiment at this point and prevent the student from making the wrong approach to the objectives of the experiment.

Data sheet and calculations. The student is to construct the pattern of the data sheet. The instructor will undoubtedly have to give assistance to the student on this part of the experiment during the first experiment.

Questions and conclusion. The student is to make a written report pertaining to the conclusion he has made while performing the experiment. This gives the student an additional opportunity to exercise self expression and to communicate to others his results and conclusions.

The questions are to be answered in the conclusion. The purpose of the questions is to aid and guide the student in writing his conclusions.

V. UNIQUENESS OF THE EXPERIMENT

The uniqueness of these experiments lies in the organization and presentation of the material in such a manner as to accomplish the following general objectives:

1. To provide adequate equipment which can be built from materials either already available or economical in cost.
2. To arouse interest on the part of the pupil by doing experiments associated with environmental

circumstances.

3. To incorporate more than one concept per experiment.
4. To encourage ingenuity and initiative on the part of the student by emphasizing the inductive method of learning. This is accomplished by the student in the planning of his experimental procedure, in the planning of how and what data to take, in the organization of data, and in the communication to others his thoughts, the discoveries he makes, and the conclusions he draws during the performance of the experiment.
5. To provide continual mental and physical participation.
6. To provide and encourage the interpretation of results by mathematical tools of expression.

Another uniqueness of these experiments is the utilization of a new type of apparatus and experimentation, which none of the current laboratory manuals incorporate, to illustrate the principles and concepts involved.

CHAPTER III

THE EXPERIMENTS

I. INTRODUCTION TO THE EXPERIMENTS

These experiments have been written for the purpose of assisting the student in gaining the utmost from a laboratory experience. In order to make a real contribution to the laboratory experience it will be necessary that the instructor and the student use the experiment in the proper manner. The directives for the use of these experiments are the following:

1. The experiments are to be used in the laboratory after the material is presented in the class. If the material is discussed in class before the experiment is performed, the student will be able to formulate and perform the experiment to a greater advantage.
2. In order to get a better understanding of the objectives to be achieved in the experiment, the student should carefully read the entire experiment before attempting to perform the experiment.
3. The students should work in small groups of two or three in each group. Working with others provides for social development.
4. Each experiment is planned to take several class periods to be finished. This gives the student

time to think and plan his activities.

5. All students should work on the same experiments at the same time. This allows the instructor to utilize the discussion period to the utmost. It also creates an atmosphere of competition between the students.
6. The instructor should give assistance only when necessary. This assistance should be given in such a manner as to enable the student to solve the problem himself.
7. Each group's method of procedure for performing the experiment and the data sheet is to be checked by the instructor before any actual experimentation takes place. This enables the instructor to check the progress of each group and to correct any wrong approach to the desired objectives of the experiment.
8. After the necessary data is collected, the student is required to do his own computations and writing of the conclusion. This allows for individual expression.

II. EXPERIMENTS

MOMENTUM

Objectives:

General:

1. To give the student a better concept of momentum.
2. To help the student gain a better concept of the mathematical relationship between velocity, mass, and momentum.

Specific:

1. To illustrate that momentum is conserved, i.e., the momentum of recoil of a rifle is equal to the momentum of the projectile.
2. To help the student obtain a better concept of projectile motion by experimentation.

Theory and explanation:

When a bullet of mass (m_2) is fired horizontally from a rifle of mass (m_1) the bullet leaves with a certain velocity. If the velocity and mass of each can be determined, the momentum of each can be calculated since the momentum of an object is the product of its velocity and its mass.

A wooden pistol and a spring are used to similate the conditions of a rifle and a bullet. The pistol is suspended, as shown in the Figures 2 and 3, so that it will swing in an arc when the spring is released.

The velocity (v_1) given the pistol by releasing the spring causes it to swing so that it rises through a vertical height (h) where its kinetic energy is converted into potential energy.

It is left for the student to derive the equation, $v_1 = \sqrt{2gh}$, for calculating the velocity of the pistol from the previous statement.

The height (h) is determined by using a pointer on the pistol which will scribe an arc tangent to a horizontal line on a plate of glass covered with lampblack.

In deriving an equation to calculate the velocity (v_2) of the spring, the student should keep in mind that when a projectile is fired horizontally the time in flight is equal to the time it would take the projectile to free fall the vertical distance (Dv).

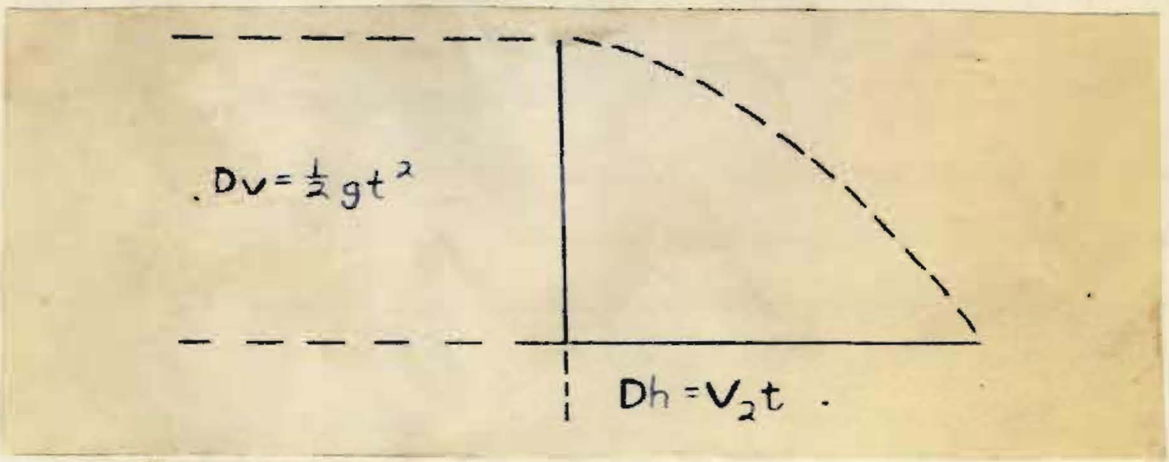

Figure 1

If the vertical distance the projectile falls and the horizontal distance (Dh) it travels are determined, the velocity of the spring can be calculated.

Further references:

Winans, John, Introductory General Physics (New York: Ginn and Company, 1952).

Dull, C. E., Metcalfe, H. C., and Brooks, W. O., Modern Physics (New York: Henry Holt and Company, Inc).

Extra Credit:

Derive an equation for calculating the velocity of the spring from Figure 1 and the information given in the previous paragraph.

Questions:

Answer the following questions before proceeding with the experiment.

1. Derive the equation $v=\sqrt{2gh}$.

____

____

____

2. How will you determine the mass of the pistol and the spring?

____

____

____

3. How will an increase in velocity affect the

momentum of an object of a given mass?

4. What is the difference in potential and kinetic energy?

5. What does action and reaction mean?

6. What does the term free fall mean?

Materials and equipment:

Wooden pistol with a pointer, ring stand, clamps, rods, string, rectangular or square glass plate, wax candle, sand, sand box, meterstick, vernier caliper, and matches.

Drawings: Apparatus

Side view:

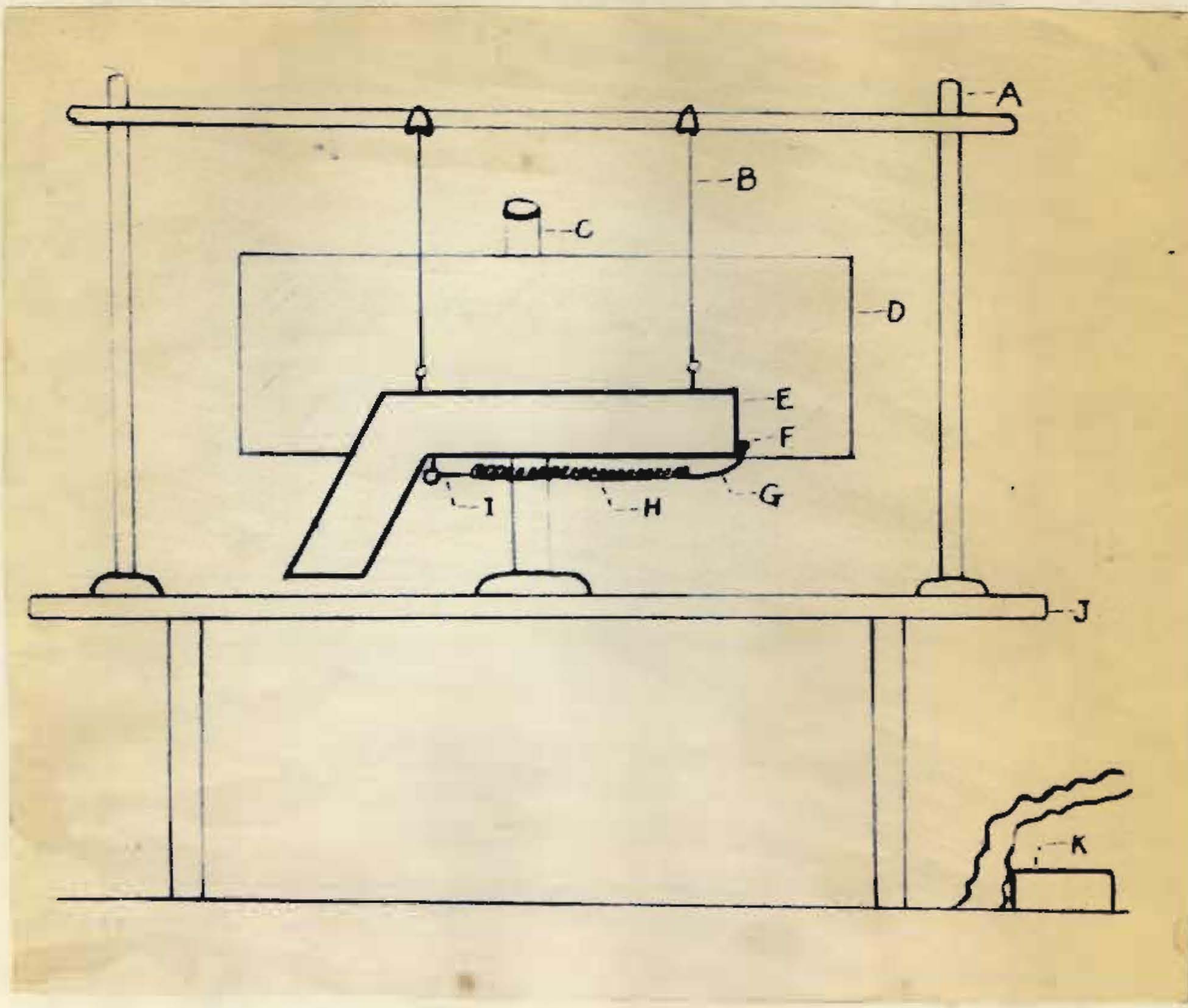

Figure 2

A.	Ring stand	G.	Wire loop
B.	String	H.	Spring
C.	Plate glass holder	I.	String
D.	Lampblacked glass plate	J.	Table
E.	Wooden Pistol	K.	Sand box
F.	Nail		

End view:

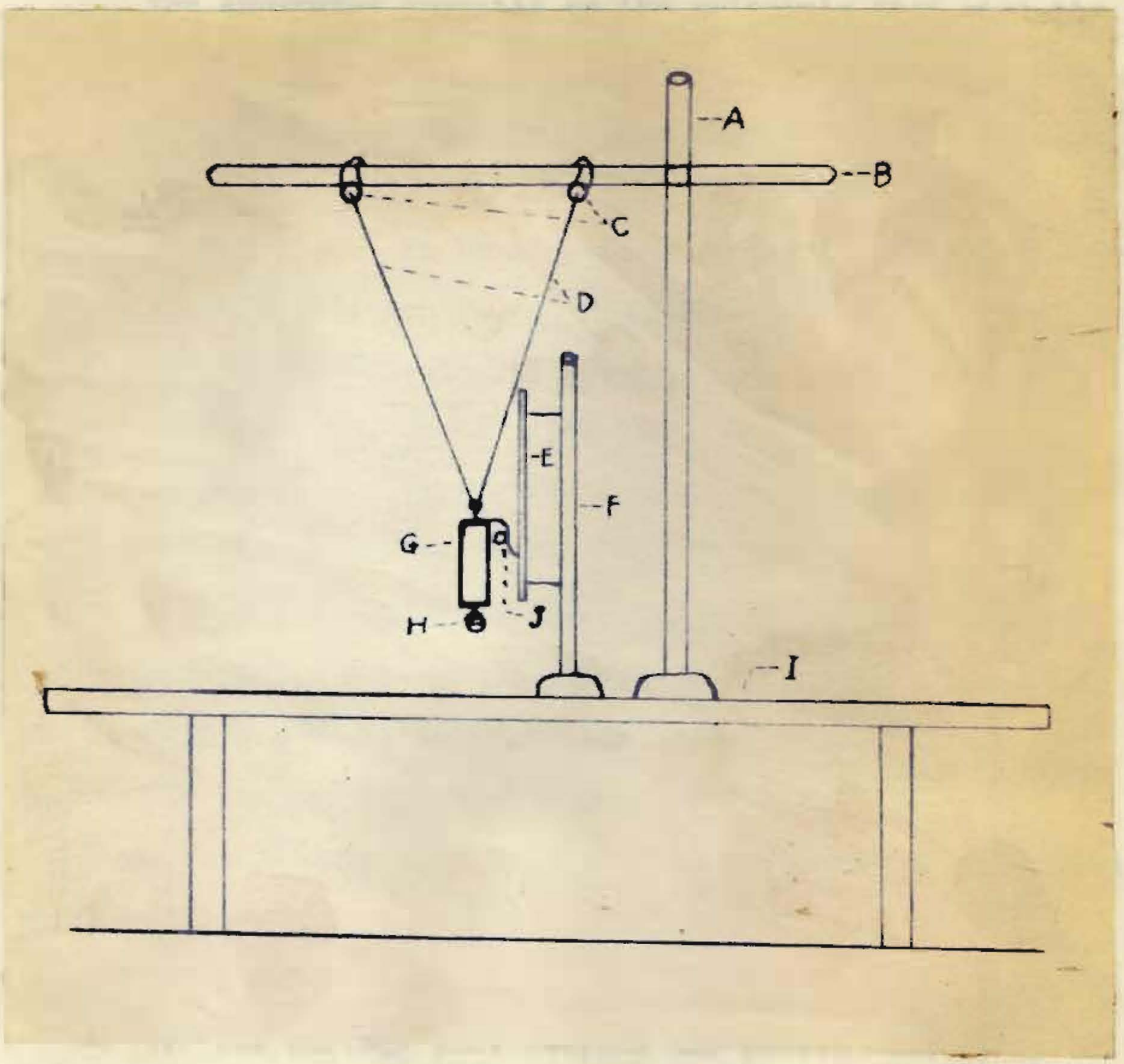

Figure 3

A. Ring stand
B. Iron rod
C. Horizontal bar
D. String
E. Carbon plate
F. Glass plate holder
G. Pistol
H. Spring
I. Table
J. Pointer

Operation of the apparatus:

The apparatus operates on the principle that when the spring is released, the momentum imparted to the pistol will cause it to swing in a direction opposite to that of the spring.

If the pistol is in a horizontal plane and the pointer on the pistol is set so it will coincide with a horizontal line drawn on the lampblacked glass plate, the pointer will scribe an arc on the glass plate as it swings back when the spring is released. This gives a means for determining the height (h) the pistol rises.

The horizontal distance the spring travels is determined by means of a sand box placed at a lower level and in the approximate position where the spring will strike. The impression the spring leaves upon striking the sand gives a means for determining the horizontal distance (Dh) traveled by the spring.

Points to observe in setting up and operating the apparatus:

1. The strings that suspend the pistol must be level.
2. The bars that support the pistol must be level.
3. A wax candle may be used to lampblack the glass plate.
4. If the plate is a rectangle or square a carpenter's square may be used to obtain a horizontal line on the glass plate.
5. The glass plate must be adjusted in its holder so

it is in a level plane and the horizontal line coincides with the pointer.

6. The glass plate must be perpendicular to the pointer.
7. The pointer should rest against the glass plate with a slight tension.
8. Refer to the Figures 2 and 3 for loading the pistol with the spring.
9. The spring is released by burning the string which holds the spring in position.

Procedure:

The students of each group plan the method of procedure and data sheet for that group. The method of procedure and the data sheet is to be checked by the instructor before proceeding with the experiment.

Each group is required to make three trials and collect the necessary data for calculating the average momentum of the pistol and the spring.

Find the difference between the momentum of the pistol and spring and compute the per cent of error with respect to the average value of the momentum of the pistol.

Work individually in answering the questions, doing the calculations and drawing the conclusions.

Procedure:

____

____

Data Sheet:

Calculations:

Questions:

The following questions are to be answered in the conclusion.

1. How does the velocity of the pistol compare with the velocity of the spring?
2. What are the main sources of error?
3. Which will cause the greater error, an error in determining the mass or an error in determining the velocity, when calculating the momentum of an object?
4. Why is it important to know about the principles of momentum?
5. In the computation of the momentum, which has the higher standard deviation, that of the spring or

that of the pistol? Why is one higher than the other?

Conclusion:

MAGNETIC FORCE

Objectives:

General:

1. To give the student a better understanding of the concept of magnetic field of force.
2. To give the student a chance to exercise his skill in plotting graphs and graphical analysis.

Specific:

1. To determine the force necessary to overcome the repulsion force of two magnetic poles.
2. To determine what relationship exists between the repulsion force of two like magnetic poles and the distance between the two poles by collecting the necessary data and plotting the repulsion force versus the distance.

Theory and explanation:

Coulomb's law states that the force with which two single magnetic poles attract or repel each other is directly proportional to the strength of each pole and inversely proportional to the square of the distance between them.

The repulsion force between two like poles can be determined by suspending magnet (A) as shown in the Figure 1 and inserting magnet (B).

The force (m) necessary to bring the magnet (A) back to its original position and the distance (d) between the poles can be determined.

Further references:

Richardson, John S. and Cahoon, G. P., Methods and Materials for Teaching General and Physical Science. (New York: McGraw-Hill Book Company, Inc., 1951).

Dull, C. E., Metcalfe, H. E., Brooks, W. O., Modern Physics. (New York: Henry Holt and Company, Inc.).

Questions.

Answer the following questions before proceeding with the experiment.

1. State Coulomb's law mathematically.

____

____

____

2. State the law of magnets.

____

____

____

3. What does the magnetic molecular theory mean?

____

____

____

4. According to Coulomb's law what type of graph should you obtain by plotting the repulsion force versus the distance between two single magnetic poles squared?

____

____

____

5. Define magnetic field of force.

____

____

____

Materials and equipment.

Two bar magnets fifteen centimeters long, thread, small pulley, balance pan of light weight, and ring stands.

Drawing: Apparatus.

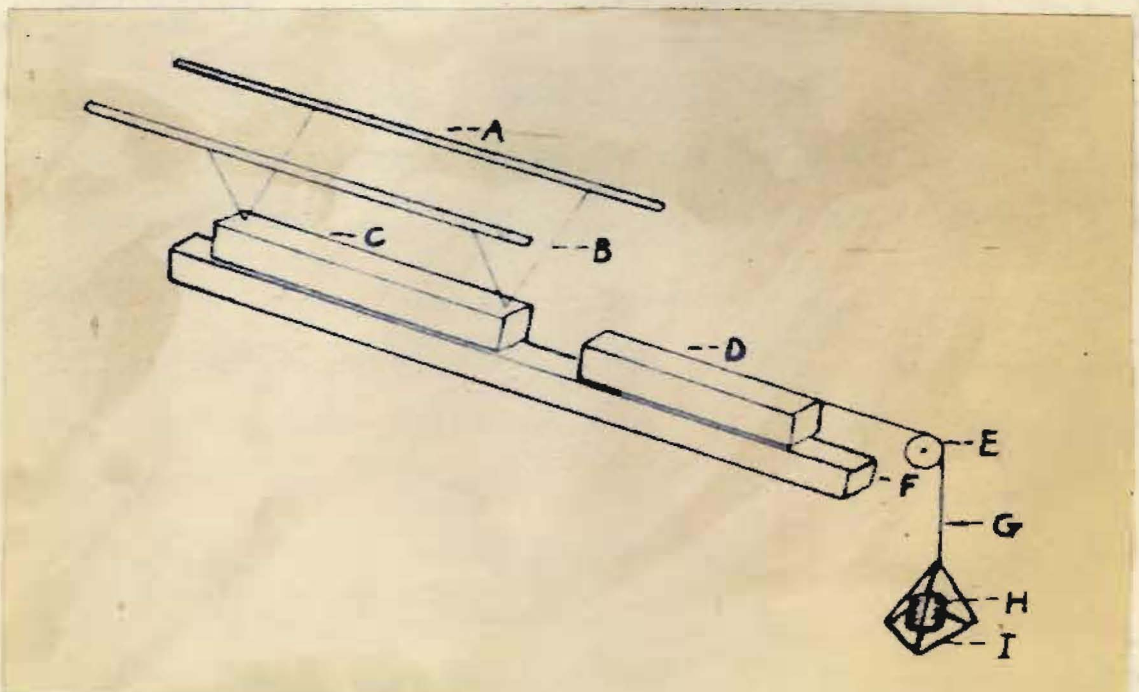

Figure 1

A. Horizontal bar
B. Thread
C. Bar magnet A
D. Bar magnet B
E. Pulley
F. Meter scale
G. Thread
H. Weight
I. Balance pan

Operation of the apparatus.

The apparatus operates on the principle that when two like poles of a magnet are brought together they repel each other. Therefore, if one magnet is suspended by threads and another magnet is placed in a position so that its N pole will repel the N pole of the suspended magnet this repulsion force will cause the suspended magnet to swing away from the other magnet.

With the suspended magnet at rest, its position may be accurately noted by an adjacent scale. The other magnet may then be placed in the correct position and weights added to the pan to pull the suspended magnet back to its original position. This gives a means for determining the repulsion force between two magnetic poles at a certain distance between the poles.

Recording this distance and force and repeating the operation for other distances, data can be collected for the plotting of several graphs.

Points to observe in setting up and operating the apparatus.

1. The supports must be parallel.
2. Scotch tape may be used to attach the threads to the magnet.
3. The pulley must be as friction-free as possible.
4. Lower the suspended magnet as close to the meter stick as possible.
5. Suspend the magnet so that it will swing in a

fairly large arc.

Procedure:

The students of each group plan the method of procedure and data sheet for that group. The method of procedure and data sheet is to be checked by the instructor before proceeding with the experiment.

Each group is to collect the necessary data for plotting three graphs: m versus d^2, m versus d, and $\frac{1}{m}$ versus d where m equals the repulsion force and d equals the distance between the poles. (It may be assumed that for a magnet fifteen centimeters long the pole is approximately one centimeter from the end).[17]

Work individually in answering the questions, plotting the graphs, and drawing the conclusions.

Procedure:

---

[17] John S. Richardson and G. P. Cahoon, *Methods and Materials for Teaching General and Physical Science* (New York: McGraw-Hill Book Company, Inc., 1951), p. 332.

Data sheet:

Calculations:

Questions:

The following questions are to be answered in the conclusion.

1. Did the curve of the graph m versus d^2 plot out as expected? Explain your answer.
2. Did any of the graphs show a direct proportion curve?
3. Did this experiment illustrate Coulomb's law to be right or wrong? Explain.

Conclusion.

WAVE LENGTH OF LIGHT EXPERIMENT

Objective:

General:

1. To gain a better concept of the length of a light wave.
2. To illustrate the principle that white light results in the colors of the visible spectrum.
3. To illustrate the principle that different colors of light have different wave lengths.
4. To give the student a chance to exercise his skill in the use of mathematics.

Specific:

1. To calculate the wave length of a certain color of light by experimentation.
2. To increase the student skill in the use of mathematical tables and trigonometric functions.

Theory and explanation:

When a white light source is placed in a position so that it glazes the surface of a phonograph record at a large angle of incident it is deflected by reflection. By sighting along the surface of the phonograph record on the opposite side of the light, Figure 1, at a large angle of incidence, the spectrum can be observed. The spectrum seems to appear on the same side as the light source and at a certain distance

WAVE LENGTH OF LIGHT EXPERIMENT

Objectives:

General:

1. To gain a better concept of the length of a light wave.
2. To illustrate the principle that white light consists of the colors of the visible spectrum.
3. To illustrate the principle that different colors of light have different wave lengths.
4. To give the student a chance to exercise his skill in the use of mathematics.

Specific:

1. To calculate the wave length of a certain color of light by experimentation.
2. To increase the students skill in the use of mathematical tables and trigometric functions.

Theory and explanation:

When a white light source is placed in a position so that it glazes the surface of a phonograph record at a large angle of incident, it is defracted by reflection. By sighting along the surface of the phonograph record on the opposite side of the light, Figure 1, at a large angle of incidence, the spectrum can be observed. The spectrum seems to appear on the same side as the light source and at a certain distance below the light source.[18]

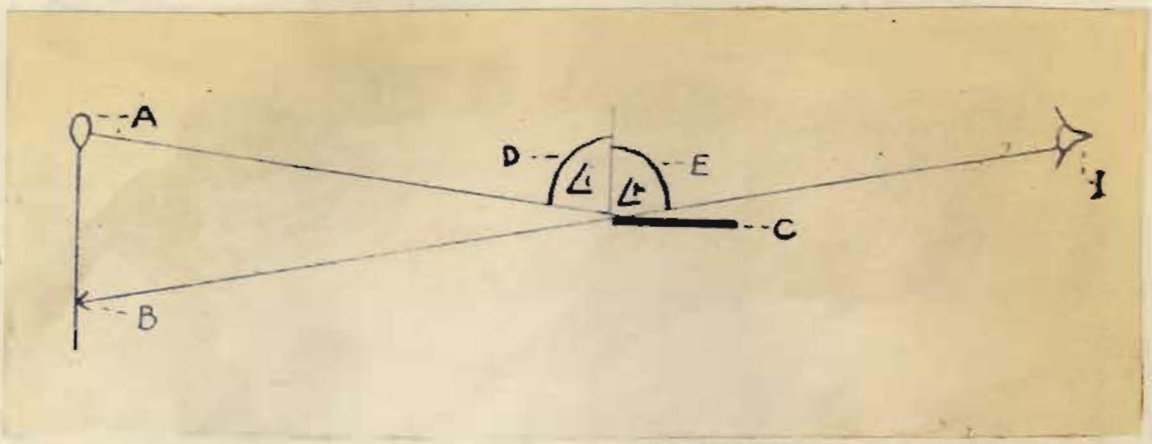

Figure 1

A. Light source
B. Spectrum
C. Phonograph record

D. ∠i = angle of incidence
E. ∠r = angle of reflection
F. Eye

The different orders of this type reflection defraction grating can be obtained by varying the angle of incident of the eye (∠2) Figure 2. The different distances at which these orders appear below the light source can be determined by placing a meter stick or tape below the light source. Knowing these distances the wave length (λ) of light can be calculated.

---

[18] Richardson and Cahoon, op. cit., p. 372.

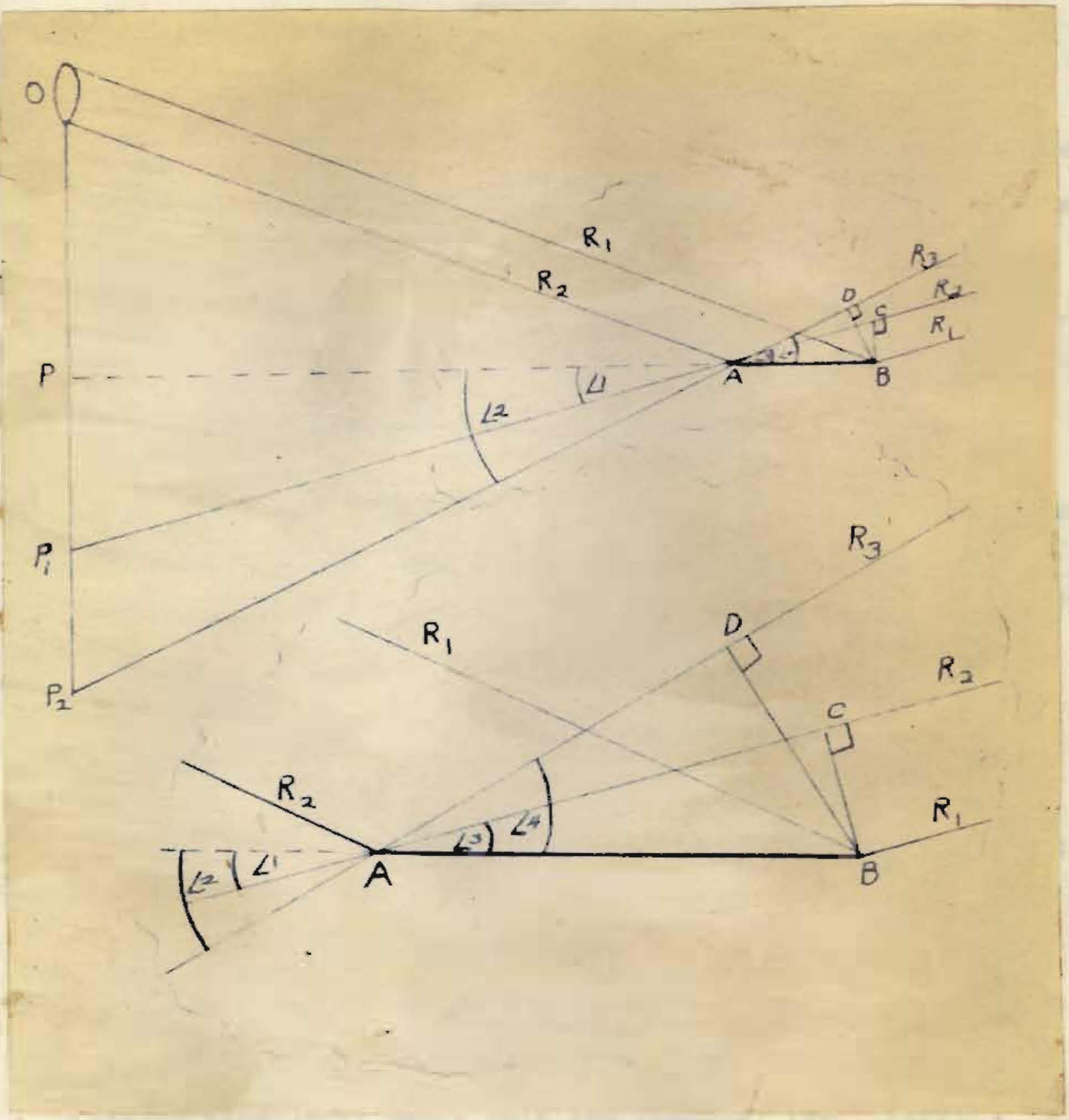

FIGURE 2

O=Light source
P=Zero order
P_1=First order
P_2=Second order
AB=Distance between the of the record

DB Perpendicular to P_2R_3
CB Perpendicular to P_1R_2
$\angle 1=\angle 3$
$\angle 2=\angle 4$
$\overline{R}$=Light ray

The difference in the paths a certain color of light travels (AC-AD), Figure 2, as it goes from one order to the next is equal to one wave length; thus the difference between AC and AD will be equal to one wave length of the light being studied.

The distances PA, PP_1, PP_2, can be determined, therefore the values of ∠1 and ∠2 can be determined by using the trigonometric function $\tan \angle 1 = \frac{PP_1}{PA}$ and $\tan \angle 2 = \frac{PP_2}{PA}$.

Since ∠1 = ∠3 and ∠2 = ∠4 the distances AC and AD can be determined by using the trigometric function $\cos \angle 3 = \frac{AC}{AB}$ and $\cos \angle 4 = \frac{AD}{AB}$. It is left for the student to derive the equation, $\lambda = d\,(\text{Cos}\,\angle 3 - \text{Cos}\,\angle 4)$, ($d = AB$ and λ = the wave length), for finding the wave length of light.

Further references:

Robertson, John K., Introduction to Optics (New York: D. Van Nostrand Company, Inc.).

Blackwood, O. H., Herron, W. B., Kelly, W. C., High School Physics (New York: Ginn and Company, Inc., 1954).

Dull, C. E., Metcalfe, H. C., Brooks, W. O., Modern Physics (New York: Henry Holt and Company, Inc., 1951).

Questions:

Answer the following questions before proceeding with the experiment.

1. Derive the equation $\lambda = d\,(\cos \angle 3 = \cos \angle 4)$

2. One angstrom equal how many centimeters?

____

____

____

3. Explain what an order of the spectrum is.

____

____

____

4. What is meant by the angle of incidence?

____

____

____

Materials and equipment:

A piece of phonograph record, rings, clamps, white light source, cardboard with a small opening in the center, meter-stick or meter tape, and telescope if available.

Drawings:

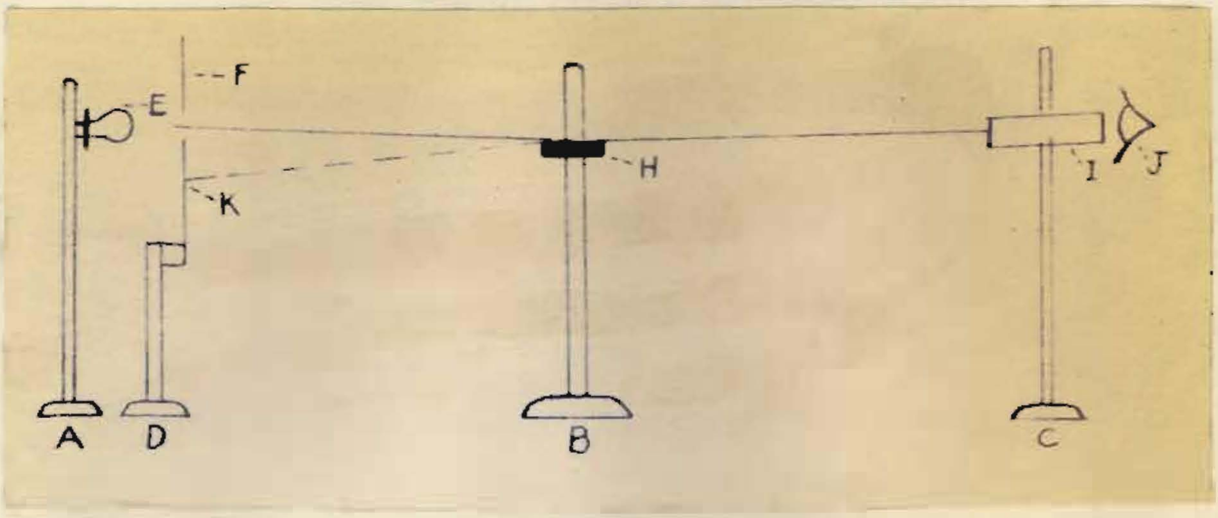

Figure 3

A, B, C, D = Ringstands	I = Telescope
E = Light bulb	J = Eye
F = Cardboard with slit	K = Where spectrum appears
G = Meter tape	
H = Piece of phonograph record	

Operation of the apparatus:

The apparatus is set up according to Figure 3 and operations on the principle of a reflection defraction grating.

The distance between the groves of the phonograph record can be determined by counting the number of groves per centimeter with the aid of a microscope or by counting the number of revolutions necessary to move the needle of a record player one centimeter across the face of the record.

Points to observe in setting up and operating the apparatus:

1. Keep the angle of incidence large.
2. Do not change the distance between the record and

the light source while taking one set of data, i.e., keep the distance constant while collecting data for one trial.

3. Use a telescope if it is available to increase the accuracy in reading the distances.

Procedure:

The students of each group plan the method of procedure and data sheet for that group. The method of procedure and data sheet are to be checked by the instructor before proceeding with the experiment.

Collect the necessary data for calculating the wave length of violet light, green light, and red light.

Use the values found in the Chemical Rubber Handbook as the theoretical values in calculating the per cent of error.

Work individually in answering the questions, doing the calculations, and drawing conclusions.

Procedure:

____

____

____

____

____

____

____

____

Data sheet:

Calculations:

Questions:

1. What are some other types of light waves?
2. What are some other methods of producing the spectrum?
3. If the distance between the groves on the phonograph record were decreased would it increase the accuracy of the experiment? Explain.
4. List the colors of the spectrum and give their approximate wave length in angstroms.
5. What type of image is the spectrum in this experiment?
6. How does the wave length of light compare with the wave length of sound? Express as a multiple of ten.

7. What relationship exists between one centimeter and one angstrom unit? How was the angstrom unit derived?

Conclusion:

TRANSISTOR EXPERIMENT

Objectives:

General:

1. To gain a better understanding of the operating principles of transistors.
2. To familarize the student with the use of transistors.

Specific:

1. To determine the current gain of a transistor by experimentation.
2. To determine the effect that the emitter voltage (input voltage) and the emitter current (input current) has on the collector current by plotting emitter voltage versus collector current and emitter current versus collector current.
3. To determine the voltage gain and power gain using the experimental current gain and a typical resistance gain.

Theory and explanation:

Transistors are constructed from two basic forms of germanium crystals; the N-type germanium crystal and the P-type germanium crystal. The N-type germanium crystal is so called because conduction is carried on by means of Negatively charged electrons. In the P-type germanium crystal conduction is effected by Positive charges.

The two most common types of transistors are the point-contact transistors and the junction transistors. The point-contact transistors consist of the N-type and P-type and the junction transistors consist of many types but the ones best suited for this experiment are the NPN-type and the PNP-type.

The point-contact transistor consists of two electrodes (emitter and collector) which make contact with a germanium crystal, and a third electrode (the base) which is soldered to the base. (It is common practice to designate the electrodes as e, c and b- emitter, collector, and base respectively.) The entire assembly is incased in a plastic housing.

The junction type transistor is a combination of P- and N-type germanium crystal which form a P-N junction. The junction transistor electrodes are soldered to their respective sections; the emitter (biased for high conductivity), the collector (biased for low conductivity), and the base (which connects to the common junction area.

The ratio of change in collector current to change in emitter current is called the current gain (α); thus $\alpha = \frac{i_c}{i_e}$ where α = the current amplification, i_e = the change in emitter current, and i_c = the resulting change in collector current.

At first glance, the current gain factor of a transistor appears disappointingly low when compared with the amplification factor of a vacuum tube. However, another gain characteristic enters the picture, namely the resistance gain which is the ratio of the output resistance (resistance between collector and base) and imput resistance (resistance between emitter and base). Thus the resistance gain $RG = r_o/r_i$ where r_o = output resistance, and r_i = input resistance.

Since the input voltage (e_i) is the product of the emitter current and the input resistance and the output voltage (e_o) is the product of the collector current and the output resistance, the transistor voltage gain (VG) equals the current gain times the resistance gain.

$VG = e_o/e_i = i_c r_o/i_e r_i = \alpha \frac{r_o}{r_i}$

Furthermore, since the input power is the product of the input voltage and the emitter current, and the output power is the product of the output voltage and collector current, the transistor power gain (PG) equals the current gain squared times the resistance gain. It is left for the student to derive the equation $P.G. = \alpha^2 \frac{r_o}{r_i}$.

The typical values of a point-contact transistor for the input and output resistances are 300 ohms and 20,000 ohms respectively.

Typical values of input and output resistances for a junction type transistor are 500 ohms and 1 megohm, respectively.[19]

Further references:

Krugman, Leonard, Fundamentals of Transistors (New York 13, N. Y., 480 Canal Street, John F. Rider Publisher, Inc.).

Dull C. E., Metcalfe, H. C., Brooks, W. O., Modern Physics (New York: Henry Holt and Company, Inc.).

Answer the following questions before proceeding with the experiment.

1. Derive the equation for power gain (PG).

2. A voltmeter is connected in either parallel or series with the circuit. Draw a diagram illustrating your answer.

3. An ammeter is connected in either parallel or series with the circuit. Draw a diagram illustrating your answer.

[19] Leonard Krugman, Fundamentals of Transistors (New York 13, N. Y.; Canal Street, John F. Rider Publisher, Inc.).

4. One ampere equals how many milliamperes?

____

____

____

5. Extra credit: Diagram a simple one-transistor radio circuit.

Materials and equipment:

N- or P-type point-contact transistor, NPN or PNP-type junction transistor, three ammeters with a one ampere scale or three milliammeters, voltmeter, electrical wire, varible resistance, and two one and a half volt dry cell batteries.

Drawings: Apparatus Circuit:

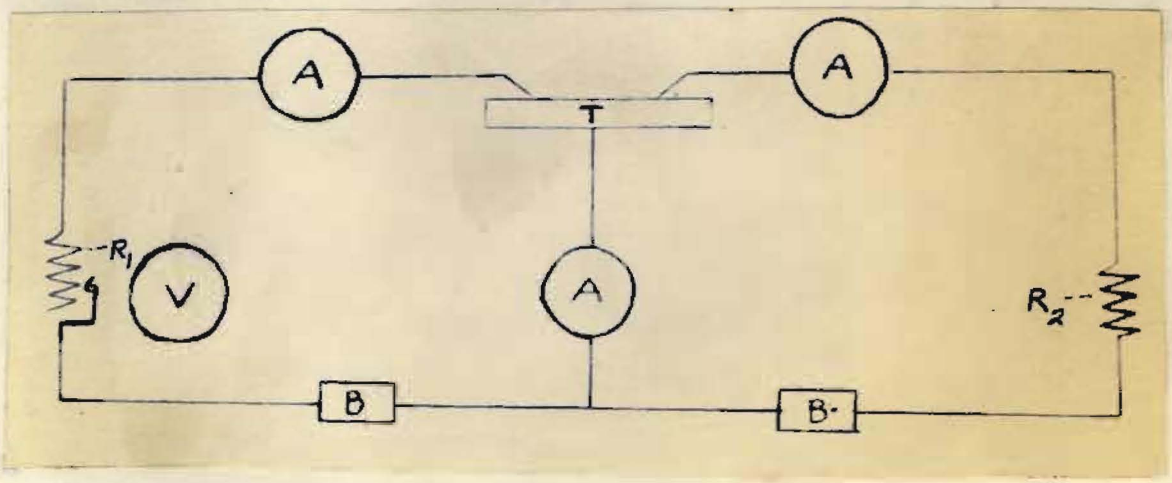

Figure 1

A = Ammeter
B = Battery
V = Voltmeter

R_1 = Varible resistor
R_2 = Load
T = Transistor

Transistor Leads:

Point-contact type Junction type

Figure 2

Battery connections for the two types of junction transistors:

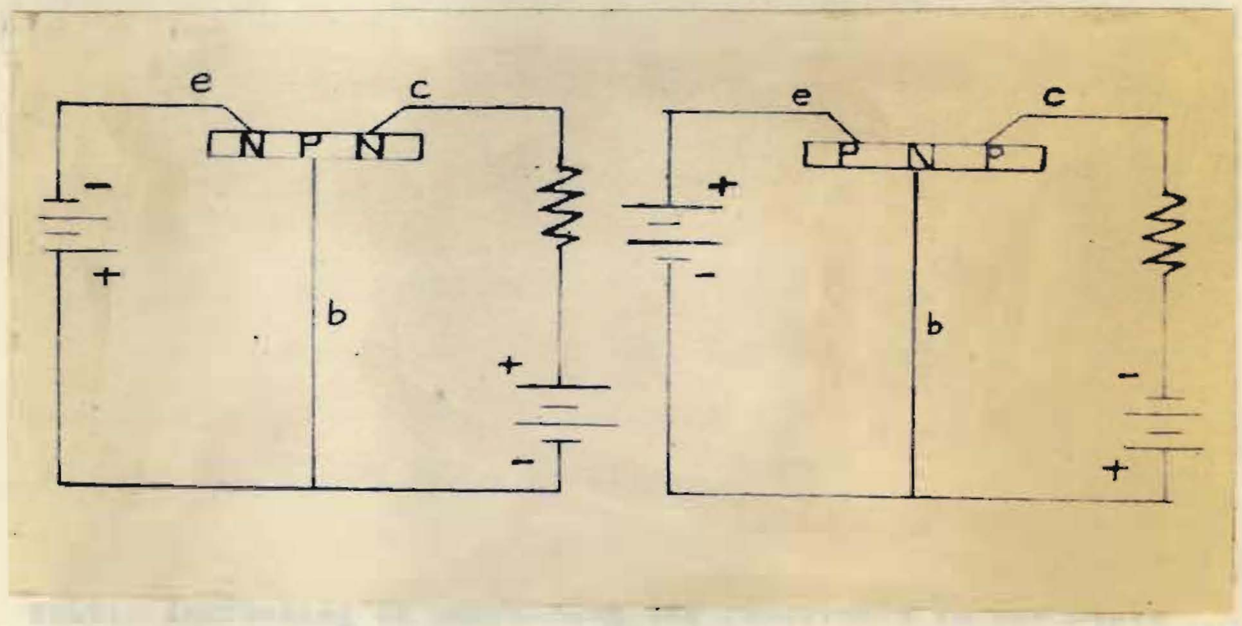

Figure 3

Battery connections for the two types of point contact transistors:

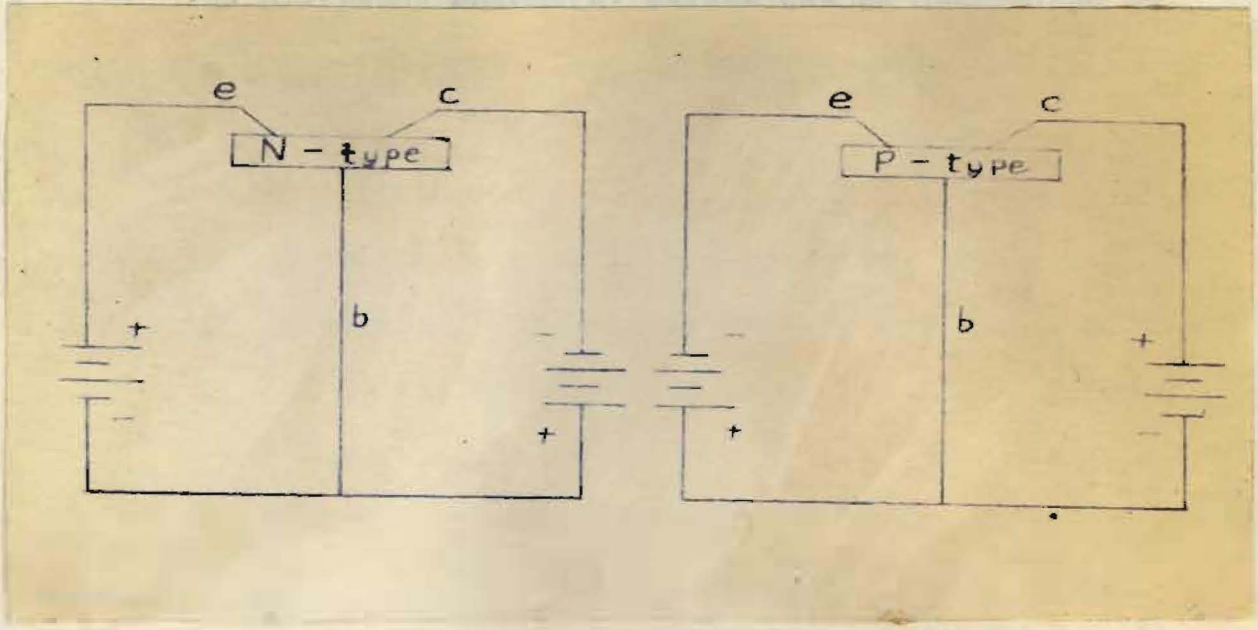

Figure 4

Operation of the apparatus:

The two one and a half volt dry cell batteries apply a potential of three volts to the input side or emitter side of the circuit. This potential may be varied by using a variable resistance connected in series with the input circuit. Increasing or decreasing the resistance in the input circuit will cause the potential applied to the emitter to vary. This variation of the potential will cause the emitter current to vary. An increase or decrease in the emitter current will cause an increase or decrease in the collector current. This gives a means for determining several values of the collector current at different emitter potentials and currents.

The different potential values can be determined by determining the potential drop across the variable resistance, then subtracting this potential drop from the total voltage applied to the emitter.

Points to observe in setting up and operating the apparatus:

1. The battery connections must be connected according to the type of transistor being used, Figures 3 and 4.
2. Know which is the emitter, the collector, and the base lead of the transistor being used, Figure 2.
3. Set up the apparatus according to Figure 1 and recheck the connections with the instructor.

Procedure:

Each group is to plan the method of procedure and data sheet for that group. The method of procedure and data sheet is to be checked by the instructor before proceeding with the experiment.

Collect the necessary data for calculating VG, PG, for plotting the input (or emitter) voltage against the collector current and for plotting emitter current against the collector current for both the point-contact and junction type transistors.

Work individually in answering the questions, in doing the calculations, and in drawing the conclusions.

Procedure:

Data sheet:

Calculations:

Questions:

The following questions are to be answered in the conclusion.

1. Which type of transistor gives the greatest current gain, the point-contact type or the junction type?
2. Which type of transistor gives the greatest power gain, the point-contact or the junction type? Explain why.
3. What is the best operating potential range of each of the two types of transistors? (hint: see graphs).
4. List some of the uses of transistors.
5. What are some very important advantages of transistors over vacuum tubes?

Conclusion:

III. RESULTS

These experiments have been used only once under actual teaching conditions and on a physics class of six students. Therefore it is impossible to make a thorough evaluation at this time.

At the close of the school term the students were asked to write their opinions and recommendations of the experiments and to compare them with the experiments in their own laboratory manual. The students' comments are the following:

> The experiments in the laboratory manual were very simple and did not benefit me as much as these experiments. These experiments, being on a somewhat higher level were a little more difficult, but were much more

interesting, which caused the principle to be understood better. I also benefited from these experiments by having to plan the procedure and the actual experience in the building and the setting up of the apparatus.

I think the experiment could be made even more interesting by having the student do his own drawings.[20]

These experiments were not included in our laboratory manual but they were more interesting and just a little harder to do than the ones in our laboratory manual. The parts of these experiments which were the hardest for me were the planning of the procedure and the writing of the conclusion. The experiments were interesting and gave me a better understanding of the material in the text. They also improved my usage of mathematics.[21]

One of the things I learned by doing these experiments is never start doing an experiment before reading the experiment and planning a method of doing the experiment. Our laboratory manual is easier and you can do most of the experiments without reading them first.

I like your experiments as they are because they are interesting and not only helped me in physics but in mathematics as well.[22]

I like these experiments better than those in the laboratory manual because the way they were presented made me stop and think before doing the experiment. I found the experiments to be difficult to understand at first because they were so different from our laboratory manual, but after reading the experiment over a couple of times it was fairly easy to understand.[23]

I really got lost on the first of these experiments but the more lost I got the more interested I became in getting the results. I think the experiments should have more information on how to do the experiment.[24]

---

[20]Sam Schiesser

[21]Stanley Clayton

[22]Ronnie Thomas

[23]Ronald Hays

[24]Scot Denison

> I think these experiments were harder to do because of being longer and more involved. They were more interesting and do more for the understanding of the concepts than our laboratory manual. These experiments helped me in my mathematics, plotting of graphs and writing of results. Also it pointed out the fact that you do not need expensive equipment to do physics experiments.[25]

The comments which appeared the most frequently were the ones on the interest shown towards the experiments, the methods of presenting the material, the increase in skill in the use of mathematics, and a better understanding of the concepts involved. This indicates that the experiments meet with some measure of success in achieving some of the objectives of science teaching.

From the observations made while the students performed the experiment, it can be stated that the students did show a more active interest in doing these experiments than had been shown in their laboratory experiments before. It is also believed that the students did more further study of the principles and concepts involved and more creative thinking and writing than they usually did, using the traditional laboratory manual.

The experiments need to be used a few more times under actual classroom situations in order to obtain a more valid evaluation of the experiments, also to determine and correct the difficulties of the experiments which may be brought out with a larger class.

---

[25]Arden Vernon

CHAPTER IV

SUMMARY AND CONCLUSION

The experiments have been organized to meet as nearly as possible the desired objectives of a laboratory experience and have been used under an actual classroom situation. The experiments are but a part of a complete manual; however they are indicative of the manner in which the remaining experiments would be written.

The objectives of a laboratory experience are numerous and varied. The major aims of a laboratory experience are: (1) to integrate the experiences in the laboratory with the desired social adjustment; (2) to help the student acquire an ability to solve his own problems; (3) to enable the student to better understand the facts, principles, and concepts of his physical environment; and (4) to develop within the student scientific attitudes, interests, appreciations, and self-expression.

The student should learn by being an active participant whenever possible. The lack of equipment should not limit the use of laboratory experimentation. Homemade equipment can be made to illustrate many of the principles and concepts of science. The facts, principles, and concepts can be learned by the inductive method to a certain degree of success.

The experiments, as shown in the discussion of the results of the experiments, seemed to give (1) the student a better understanding of the principles and concepts involved; (2) a greater interest in laboratory experiments; (3) a better understanding of the relationship between mathematics and physical application; and (4) caused the student to do more creative thinking and writing than the traditional laboratory experiments.

The experiments are by no means perfect and will be improved by continual use. However, at this time there is no real evidence which would indicate a change in the general form of the experiments. If the experiments are to be used again there should be some minor changes in the questions and more further references listed. Also a testing program should be set up to obtain a better evaluation of the experiments.

The author has drawn from this study the conclusion that the experiments have fulfilled to some degree all the purposes of the problem which was to include certain objectives of education.

In the future, if the preceding experiments prove to be highly successful, additional experiments of this type will be organized to further meet the needs of the student and the objectives of education.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

Ahner, Walter L. Amsco Workbook and Laboratory Manual in Physics. New York: Amsco School Publications, Inc., 1956.

Baker, D. Lee, Robert N. Fuller, and Raymond B. Brownlee. Laboratory Experiments in Physics. New York: Allyn and Bacon, Inc., 1953.

Black, Max. Critical Thinking. New York: Prentice-Hall, Inc., 1946.

Blackwood, Oswald H., Wilmer B. Herron, and William C. Kelly. Workbook and Laboratory Manual to Accompany High School Physics. New York: Ginn and Company, 1954.

Brown, H. Emmett and Edward C. Schwachtgen. Laboratory Manual Physics: The Story of Energy. Boston: D. C. Heath and Company, 1950.

Burns, et al. Activities in Physics. New York: D. Van Nostrand Company, Inc., 1954.

Dull, Charles E., H. Clark Metcalfe, and W. O. Brooks. Modern Physics. New York: Henry Holt and Company, Inc., 1954.

Dull, Charles E., H. Clark Metcalfe, and John E. Williams. Physics Workbook. New York: Henry Holt and Company, Inc., 1955.

Elliott, L. Paul, William F. Willcox, and Irving Orfuss. Laboratory Manual and Workbook for Physics. New York: The Macmillan Company, 1958.

Frederick, Robert W., Clarence E. Ragsdale, and Rachel Salisbury. Directing Learning. New York: D. Appleton-Century Company, 1938.

Heiss, Elwood D., Ellworth S. Obourn, and Charles W. Hoffman. Modern Methods and Materials for Teaching Science. New York: The Macmillan Company, 1951.

Krugman, Leonard. Fundamentals of Transistors. New York 13, N. Y., 480 Canal Street: John F. Rider Publisher, Inc., 1956.

Richardson, John S. and G. P. Cahoon. Methods and Materials for Teaching General and Physical Science. New York: McGraw-Hill Book Company, Inc., 1951.

Winan, John. Introductory General Physics. New York: Ginn and Company, 1952.

B. PUBLICATIONS OF LEARNED ORGANIZATIONS

"A Report of the President's Commission on Higher Education," Higher Education for American Democracy, Establishing the Goals, Vol. 1. New York: Harper and Brothers Publishers, 1948.

Educational Planning Commission, The Life Adjustment Program. Topeka, Kansas: Kansas State Teachers Association, Revised March, 1950.

Henry, Nelson H., editor: "Science Education in American Schools," The Forty-Sixth Yearbook of the National Society for the Study of Education. Part I. Chicago: The University of Chicago Press, 1947.

C. PERIODICALS

Brandwein, Paul F. "Obstacles to Increased Physics Enrollment," American Journal of Physics, 23:537-41, November, 1955.

Kruglak, Hayn. "The Effect of High School Physics and College Laboratory Instruction on Achievement in College Physics," Science Education, 39:219-22, April, 1955.

Little, Elbert P. "In These Beginnings," The Science Teacher, 24:315, November, 1957.

Mallinson, George Greisen. "The Role of Physics in the Emerging High School," School Science and Mathematics, 55:211-16, March, 1955.

Maul, Ray C. "Is the Science Teacher Shortage a Curriculum Factor?" The Science Teacher, 23:181-3, May, 1956.

Maul, Ray C. "Science Teachers for Tomorrow," The Science Teacher, 20:173-5, September, 1953.

Michels, Walter C. "The Teaching of Elementary Physics," Scientific American, 198:30, April, 1958.

Physical Science Study. "Building a New Structure," The Science Teacher, 24:315, November, 1957.

Sutton, Richard M. "The College Teachers Look at High School Science," Science Teacher, 22:184, May, 1956.