THESIS APPROVED BY

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Major
Adviser

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May 11, 1935
A STUDY OF THE PRESENT STATUS
OF HIGH SCHOOL PHYSICS IN THE
STATE OF NEBRASKA

EARL H. SCHROER B.S.

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE
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IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
OF MASTER OF ARTS
IN THE DEPARTMENT
OF EDUCATION

OMAHA, NEBRASKA
JUNE 1952
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Chapter I

INTRODUCTION

The High School Section of the Nebraska Academy of Sciences, meeting in Fremont, Nebraska April, 1929, considered in open session and passed by a unanimous vote, the following Resolution:

Resolved:—That the Department of University Extension: University of Nebraska, in cooperation with the State Department of Education, shall have prepared and shall publish a Science Syllabus for use in the schools of Nebraska.

Resolved:—That this syllabus shall be as comprehensive and as usable as are the Syllabi published to aid in the teaching of secondary school sciences in the States of Missouri, Kansas, Minnesota, and other western commonwealths.

Resolved:—That a copy of these Resolutions be forwarded by the Secretary (or President) of the Science Section to the Director of University Extension, and to the State Superintendent of Public Instruction, at Lincoln, Nebraska.

A committee of three was then appointed to consider the question of preparation of the Syllabus with instructions to report at the next annual meeting of the Academy. No chairman was appointed and the committee held only one very short meeting.

1. Minutes of Science Section, Nebraska Academy of Science, 1929.
The committee submitted copies of the resolution to the science sections of the Nebraska State Teachers Association at the following fall meeting. Several endorsed it that year while two sections held it over for investigation and discussion, endorsing it at the next yearly meeting.

The following comments on the subject were received by the committee from the State Superintendent of Public Instruction:

"On the general proposition, there would be some danger in having a syllabus such as you mention. One danger would be an attempt to standardize the work of science in all subjects, taking away the right of the individual teacher and the individual school board to fix their own course of study to meet their own local problems. For instance, your problems are not to be compared with a school like Chappell, Nebraska.--------

-----I am glad that your Academy of Sciences is agitating this question. I think your resolution is all right if we had the personnel and the money. The personnel we could undoubtedly find. We have a chance to find the money every two years. The finding has not been good lately."

In the spring of 1931 the committee reported the progress made and went on record as further favoring

1. J. J. Guenther, Paper read before the Science Section of the Academy of Science. Spring meeting, 1931.
the construction of a science syllabus for the following reasons: 1

1. It would be manifestly too expensive an undertaking for the State Department of Public Instruction to publish a High School Manual for every teacher. At the present time a Superintendent and in some cases, a principal or the school library has a copy which is seldom used.

2. Because the space allotted to each subject in the High School Manual is so limited that only a very scant outline of the subject material can be presented.

3. Teachers want more than outlines; they want methods, suggestions as to material, experimental procedure, simple demonstrations, data, and instruction. In short they would appreciate a symposium of actual teaching procedure as carried on in our schools which the syllabus would make available.

4. We want our own syllabus and not one handed to us from other states. (Some are in very definite use in the state, particularly that of Missouri which is very fine).

Little or no progress has been reported since that time. It is hoped, however, that at the 1932 meeting of the Nebraska Academy of Sciences the subject will again be introduced.

1. Ibid.
Chapter II

OBJECT OF THE INVESTIGATION

The action of the various science sections of the Nebraska State Teachers Association point to a recognized need for organization of science. The action caused by this proposition sponsored by the Academy of Sciences is indicative of a previous hidden interest by the science teachers in this state.

That this interest is not a local one is shown by the following report in School Science and Mathematics:

The Wisconsin State Teachers Association has appointed a committee to study the status of science teaching in the state, and has set aside funds for all the necessary expenses of the committee. The primary aim is to improve science teaching in Wisconsin. Professor Davis is interested in finding out what similar projects are being carried on in other states and will welcome correspondence on the subject.

This movement is indeed commendable and worthy of attention. While other states are curtailing educational expenditures even to the extent of eliminating essential activities, Wisconsin is appropriating funds for new investigations, and furnishing the committee money for postage, traveling expenses and printing. Hats off to the Badger state.

Although not so strongly endorsed and lacking the financial backing given by our neighboring state, the writer has attempted to aid the committee, appointed by the Academy of Science, in securing information concerning the teaching of physics in Nebraska.

The purpose of the present investigation is to determine in general, whether or not a need exists for the construction of a science syllabus. Specifically the aim is to secure definite information concerning the trend of the teaching of physics in this state.

It is desired to determine what changes are taking place in the subject and what teachers' opinions are on suggested improvement as well as the degree of uniformity of instruction.

The purpose is to determine how these changes conform with the general changes taking place in our educational system and whether these changes are beneficial to the better teaching of the sciences.
Chapter III

METHODS USED IN THE INVESTIGATION

In conducting scientific studies it is obvious that a complete survey is necessary before conclusions of value can be drawn. The present writer undertakes to make this study as complete as possible by using three methods of investigation.

First, on the assumption that the science teachers of Nebraska are the ones affected, a questionnaire was used to secure from them such information as would seem important in an investigation of this kind. The second part of the study was made by comparing the syllabi from those neighboring states possessing them. The survey was completed by studying and comparing recent investigations in this field. The purpose was to secure an insight into the future changes in science teaching.

THE QUESTIONNAIRE

Although fully aware of the inadequacies in the questionnaire method of collecting data, its use was made necessary because of the conditions of the
investigation. To increase the validity of this method a copy of the following questionnaire was mailed to the Superintendent of all High Schools in Nebraska, having a faculty of ten or more teachers, asking the cooperation of his science teacher in collecting the required data.

The degree of validity of the responses is shown by the fact that 154 schools replied to the 212 inquiries sent, a percentage of 72.6. From schools having enrollments of 200 or more the per cent of replies was 88 indicating a greater interest from more experienced teachers.

The replies from the questionnaire are shown in Table Ia where the schools have been grouped according to the High School enrollment for this year. The types of responses are also shown. A study of Table I points to the significant fact that 10 schools are not teaching physics and that one of these schools has an enrollment of over 400 pupils. Schools offering physics on alternate years number 20 while 123 are teaching the subject at this time.

1. Page 8.
A QUESTIONNAIRE ON HIGH SCHOOL PHYSICS

1. Location of school ________, state __________.

2. Number of pupils in high school ________.

3. Number pupils taking physics this year ________ ________

   (a) Physics in offered in which grade? 10__, 11__, 12__.
   (b) No. of sections ____, (c) No. periods per week ______.
   (c) No. laboratory periods per week ________.

4. Has this number of pupils during the past three years
   been (a) increasing (b) decreasing (c) fairly constant?
   Underline one.

5. How many years including the present have you taught high
   school physics? ______years. Years in present school? __

6. Check the types of instruction you are now using:

   (1) Question and answer   (5) Unit plan
   (2) Teaching from experiment   (6) Socialized recitation
   (3) Project method
   (4) Contract plan

7. Please indicate the approximate time in weeks for each of
   the following divisions of physics:

<table>
<thead>
<tr>
<th>No. of Weeks</th>
<th>(6)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>____________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metric system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanics of fluids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanics of solids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Please indicate to the right of No. 7 the order in which
   you teach the above using Numbers 1 to 9.

9. Also indicate to the right of No. 7 the number of indivi-
   dual experiments your laboratory apparatus permits for
   each unit.
10. If time prevented teaching all the above divisions, which in your opinion could be most conveniently shortened?

11. Please check the following phases of subject matter according to your opinion of student difficulty. Rate from 1 to 10 (10 the most difficult) making those of equal difficulty have the same rating.

- Density
- Force and pressure
- Pascal's principle
- Boyle's law
- Principle of Archimedes
- Laws of Newton
- Falling bodies
- Work, power, and energy
- Machines
- Gas problems
- Specific heat
- Expansion
- Change of state
- Nature of light
- Mirrors
- Lenses
- Optical instruments
- Color
- Invisible radiations
- Metric system
- Hygrometry
- Industrial applications
- Transference of heat
- Magnetism
- Static electricity
- Current electricity
- Effects of electricity
- Electrical laws
- Induced currents
- Applications of induced currents
- Nature and speed of sound
- Reflection and reinforcement
- Vibrating strings

12. Please underline those in No. 11 that in your opinion could be omitted with least effect on minimum essentials.

13. To the right of the different terms in No. 11 please indicate the way you think the laboratory work over that material, can be best accomplished, taking into consideration your equipment and size of group. Use the following symbols; P for group or individual projects, I for individual experiment, T for teacher demonstration, G for groups of more than two. (Consider 2 pupils working together as an individual experiment.) ★Consider as a project any experiment that can be performed outside of classroom.

14. Please indicate, if any, the following standard tests you have used during the past 3 years:

(1) Iowa Physics tests
(2) Hughes Physics scales
(3) Thurstone Vocational Guidance test in Physics
(4) Columbia Research Bureau Physics Test
(5) Instructional Tests in Physics by Glenn
(6)
15. In constructing a science syllabus for high school physics, which of the following would you suggest to be needed most for more uniform instruction in this state? Please check.

___ Special descriptions of classroom demonstrations to be performed by the teacher?
___ Methods for the solution of difficult problems?
___ Outline of laboratory work with reference to material and time?
___ Models of standard tests with standard scores for comparing work?
___ Outline of classroom work with reference to questions, material, and time?

Thank You

Sign if you wish
TABLE I  
REPLIES FROM SCHOOLS  

<table>
<thead>
<tr>
<th>Type of Reply</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
</tr>
<tr>
<td>Physics taught each year</td>
<td>14</td>
</tr>
<tr>
<td>Physics taught on alternate years</td>
<td>1</td>
</tr>
<tr>
<td>Physics not taught</td>
<td>1</td>
</tr>
</tbody>
</table>

The first part of the questionnaire was used to secure information on the class enrollment, the grade in which the subject was offered, and the general enrollment changes. Question five requested information on teaching experience of the Science teacher.

Data obtained from these questions are shown in Tables IIa, IIIb, IVc, and Vd. Each table is a composit grouping of the first five questions.

a. Page 13  
b. Page 14  
c. Page 15  
d. Page 17
arranged according to the size of the school, based on present enrollment. The length of recitation was not recorded because, with but three exceptions, all schools reported a seven period week consisting of two double laboratory periods and three single periods of recitation. The exception in two cases indicated ten periods a week including supervised study, while one was limited to five one hour periods. The average enrollment in any one class being 41. Local conditions in that school made a division impossible this year.

The larger schools reported the boys greatly out numbering the girls with the average approaching somewhat even terms in the smaller schools. This is to be expected because of the fewer electives in the latter schools.

It is significant to note that the larger systems (an enrollment of more that 200) seem to favor the eleventh grade for offering physics, while the trend is in favor of the twelfth grade in the schools of lesser size.
TABLE II

GENERAL INFORMATION ABOUT PHYSICS AS TAUGHT IN NEBRASKA HIGH SCHOOLS, AND SCIENCE TEACHERS FOR SCHOOLS HAVING ENROLLMENTS ABOVE 400

<table>
<thead>
<tr>
<th>School</th>
<th>Average Enrollment per class</th>
<th>Grade Offered</th>
<th>Enrollment Changes</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Girls</td>
<td>Boys</td>
<td></td>
<td>Present School</td>
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<tr>
<td>A</td>
<td>5</td>
<td>18</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>B1</td>
<td>11</td>
<td>15</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>20</td>
<td>11</td>
<td>Increase</td>
</tr>
<tr>
<td>D1</td>
<td>-</td>
<td>--</td>
<td>11, 12</td>
<td>Increase</td>
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<td>E</td>
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<td>4</td>
<td>18</td>
<td>11, 12</td>
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<td>25</td>
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<td>30</td>
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1--Offering more than one section.
2--Offered alternate years.
### TABLE III

GENERAL INFORMATION ABOUT PHYSICS AS TAUGHT IN NEBRASKA HIGH SCHOOLS, AND SCIENCE TEACHERS FOR SCHOOLS HAVING ENROLLMENTS FROM 200 TO 400

<table>
<thead>
<tr>
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<td>11, 12</td>
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</table>

1. More than one section

2. Offered alternate years
TABLE IV

GENERAL INFORMATION ABOUT PHYSICS AS TAUGHT IN NEBRASKA HIGH SCHOOLS, AND SCIENCE TEACHERS FOR SCHOOLS HAVING ENROLLMENTS BETWEEN 100 AND 200

<table>
<thead>
<tr>
<th>School</th>
<th>Average Enrollment per class</th>
<th>Grade Offered</th>
<th>Enrollment changes</th>
<th>Experience</th>
<th>Present school</th>
<th>Total years</th>
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<td>Boys</td>
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<tr>
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<td>13</td>
<td>11</td>
<td>Decrease</td>
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<td>3</td>
</tr>
</tbody>
</table>

* More than one section
Enrollments were reported to be decreasing in only eleven schools. More "increased enrollments" were reported by the larger systems than by the smaller schools. This may, in part, be explained by acute conditions of employment causing older pupils, in the larger localities, to remain in or return to school.
**TABLE V**

GENERAL INFORMATION ABOUT PHYSICS AS TAUGHT IN NEBRASKA HIGH SCHOOLS, AND SCIENCE TEACHERS FOR SCHOOLS HAVING ENROLLMENTS LESS THAN 100

<table>
<thead>
<tr>
<th>School</th>
<th>Average Enrollment per class</th>
<th>Grade Offered</th>
<th>Enrollment changes</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>girls</td>
<td>boys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
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</tr>
<tr>
<td>B</td>
<td>3</td>
<td>11</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>5</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>Constant</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
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<td>12</td>
<td>Constant</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>10</td>
<td>12</td>
<td>Increase</td>
</tr>
<tr>
<td>G</td>
<td>7</td>
<td>21</td>
<td>11, 12</td>
<td>Increase</td>
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<td>9</td>
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<td>0</td>
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<td>11, 12</td>
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<td>11, 12</td>
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<td>5</td>
<td>11, 12</td>
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<td>M</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>Constant</td>
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<td>N</td>
<td>2</td>
<td>9</td>
<td>12</td>
<td>Constant</td>
</tr>
<tr>
<td>O</td>
<td>0</td>
<td>11</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>P</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>Constant</td>
</tr>
<tr>
<td>Q</td>
<td>2</td>
<td>10</td>
<td>12</td>
<td>Increase</td>
</tr>
<tr>
<td>R</td>
<td>0</td>
<td>7</td>
<td>11, 12</td>
<td>Constant</td>
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<tr>
<td>S</td>
<td>8</td>
<td>4</td>
<td>12</td>
<td>Constant</td>
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<tr>
<td>T</td>
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<td>Constant</td>
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<tr>
<td>V</td>
<td>3</td>
<td>4</td>
<td>11</td>
<td>Decrease</td>
</tr>
<tr>
<td>W</td>
<td>6</td>
<td>10</td>
<td>11, 12</td>
<td>Constant</td>
</tr>
<tr>
<td>X</td>
<td>-</td>
<td>--</td>
<td>12</td>
<td>Constant</td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>8</td>
<td>12</td>
<td>---</td>
</tr>
</tbody>
</table>

A summary of teaching experience shows that out of 154 teachers replying, all but 10 have had two or more years of science teaching experience. Thirty-two are teaching their first year in their present schools.
another result of present conditions. The greatest range of experience reported was twenty-seven years in one school.

The different types of instruction used in this state is summarized in Table VI. The results show that 102 teachers favor teaching from experiments while 97 prefer the question and answer method. In no instance did a teacher confine his choice to one method. Many reported using a combination of several types. The socialized recitation was used in 43 schools, while

**TABLE VI**

**TYPES OF INSTRUCTION USED**

<table>
<thead>
<tr>
<th>Different Types</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
</tr>
<tr>
<td>1. Question and answer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
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<tr>
<td>2. Teaching from</td>
<td></td>
</tr>
<tr>
<td>experiment</td>
<td>11</td>
</tr>
<tr>
<td>3. Project method</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>4. Contract plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>5. Unit plan</td>
<td></td>
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<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>6. Socialized recitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>
33 advocated the project method. The unit plan is in use in 30 schools while only 14 reported using the contract plan. The data reported seems to indicate a close adherence to two methods with little tendency to the newer or more recently suggested plans.

In Table VII is presented the average approximate time in weeks spent on the different division of subject matter as outlined by the questionnaire. The divisions are those generally found in standard text books. A consistancy in time spent on the different units is quite apparent, although a few individual schools showed a wide variation in some one subject. The only out-standing differences noticed, are for those schools of large enrollment. This is evident in the time allotment of only 1.7 weeks for magnetism and 5.6 weeks for light. The decrease in time spent on light with school enrollment is to be expected from an apparatus standpoint.

The importance of the order of teaching subject matter can not be over looked. The relative distribution of the different division of the subject matter

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TABLE VII
AVERAGE APPROXIMATE TIME IN WEEKS
SPENT ON DIFFERENT DIVISIONS OF PHYSICS

<table>
<thead>
<tr>
<th>Division of Subject</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
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<tr>
<td>Metric system</td>
<td>1.3</td>
</tr>
<tr>
<td>Mechanics of fluids</td>
<td>4.8</td>
</tr>
<tr>
<td>Mechanics of solids</td>
<td>5.8</td>
</tr>
<tr>
<td>Light</td>
<td>5.6</td>
</tr>
<tr>
<td>Heat</td>
<td>5.4</td>
</tr>
<tr>
<td>Sound</td>
<td>2.4</td>
</tr>
<tr>
<td>Magnetism</td>
<td>1.7</td>
</tr>
<tr>
<td>Electricity</td>
<td>7.3</td>
</tr>
<tr>
<td>Review</td>
<td>1.5</td>
</tr>
</tbody>
</table>

is shown in Table VIII\(a\), where both the frequency and position are recorded. Out of 126 schools teaching physics 124 start with the metric system. This is followed in 108 schools with the study of the mechanics of fluids while 18 follow the metric system with the
mechanics of solids. The same number place the mechanics of fluids third. The position of the mechanics of solids is placed third by 84 schools. Light, heat, and sound have a wide range of positions. The only significance is given to heat which is placed fourth by 71 schools. The arrangement of magnetism and electricity is determined by the position of the other

### TABLE VIII

ORDER OF TEACHING SUBJECT MATTER IN HIGH SCHOOL PHYSICS

<table>
<thead>
<tr>
<th>Subject</th>
<th>Frequency and Position</th>
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<td>1  2  3  4  5  6  7  8  9</td>
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<tr>
<td>Metric system</td>
<td>124 --- 1 1 -- -- -- -- --</td>
</tr>
<tr>
<td>Mechanics of fluids</td>
<td>--- 108 18 -- -- -- -- --</td>
</tr>
<tr>
<td>Mechanics of solids</td>
<td>2 18 84 4 3 1 1 11 --</td>
</tr>
<tr>
<td>Light</td>
<td>--- --- 2 11 29 36 8 37 --</td>
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<tr>
<td>Heat</td>
<td>--- --- 19 71 22 19 2 1 --</td>
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<tr>
<td>Sound</td>
<td>1 --- --- 35 35 15 26 10 --</td>
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<tr>
<td>Magnetism</td>
<td>--- --- --- 1 32 28 60 1 --</td>
</tr>
<tr>
<td>Electricity</td>
<td>--- --- 1 -- --- 31 27 61 --</td>
</tr>
<tr>
<td>Review</td>
<td>--- --- --- --- --- -- 79 --</td>
</tr>
</tbody>
</table>
division of subject matter but in almost every case electricity follows magnetism. The wide distribution seems to be affected by a choice of teaching light or electricity last. This irregularity is caused in most cases by the selection and use of a text book.

The most objectionable criticism to this variation in order of teaching is the handicap pupils encounter on changing schools. A possible solution seems to be in more uniform arrangement in text books, or a more complete course of study.

TABLE IX

AVERAGE NUMBER OF INDIVIDUAL EXPERIMENTS APPARATUS PERMITS

<table>
<thead>
<tr>
<th>Division of Subject</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Metric system</td>
<td>4.4</td>
</tr>
<tr>
<td>Mechanics of fluids</td>
<td>8.0</td>
</tr>
<tr>
<td>Mechanics of solids</td>
<td>9.5</td>
</tr>
<tr>
<td>Light</td>
<td>7.2</td>
</tr>
<tr>
<td>Heat</td>
<td>8.7</td>
</tr>
<tr>
<td>Sound</td>
<td>3.9</td>
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<tr>
<td>Magnetism</td>
<td>2.6</td>
</tr>
<tr>
<td>Electricity</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Individual laboratory apparatus for the different schools is summarized in Table IX. The same divisions were made in the subject matter and the average was found for the schools in each of the arbitrarily selected groups. Comparison with the total average, indicates little variation in equipment with a natural increase for those subjects requiring the most time.

The remaining part of the questionnaire deals with the collection of teachers' opinions. The validity of this type of data depends largely upon the source and purpose of the investigation. The percentage of replies in this study seem to indicate a high degree of interest while the teaching experience of those questioned tends to express more than average authority.

The purpose of question ten was to secure opinions on those parts of the course in physics that could be conveniently shortened. This is in keeping with a communication made by Joseph Jannson, Vice-President of the Association of Colleges and Secondary Schools of the Middle States and Maryland, read to the Physics Section at the Thirty-first Annual Meeting of the Central Association of Science and Mathematics Teachers.
The Secretary's report of the letter reads in part:  

It was pointed out that due to the rapid growth in the subject matter of physics and its application, it is no longer desirable to attempt a comprehensive treatment of all subdivisions of physics in a one year high school course. An attempt is being made by the Maryland Association to reorganize the physics course for more thorough teaching of the subjects attempted even though many equally desirable questions are omitted from the course. The letter was written with the purpose of instigating similar action and cooperation in the North Central Association.

A study of the results in Table Xa indicates that 34 teachers favor shortening the study of light while electricity was selected by 30 for next choice. Sound and the mechanics of solids were the next in order having been selected by 25 and 24 teachers respectively. No divisions of the subject escaped. Heat, with 21 favoring its curtailment, was next, followed by the mechanics of fluids with 19, magnetisms 11, metric systems 4, and review 3.

Although no outstanding selection is noticed, it appears that light and electricity, despite the rapid growth in these two fields, is the choice of

1--F. M. Carl, Secretary, Report of Meeting of Physics Section. School Science and Mathematics. XXXII: (February 1932) P. 197.
teachers in schools all sizes. This may be partly explained by reference to Table XIa, where a summary of teacher's opinion of the degree of difficulty, shows that units, in each of these subjects, were

### TABLE X

TEACHER OPINION OF PART THAT COULD BE SHORTENED

<table>
<thead>
<tr>
<th>Division of Subject</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Metric system</td>
<td>--</td>
</tr>
<tr>
<td>Mechanics of fluids</td>
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</tr>
<tr>
<td>Mechanics of solids</td>
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<td>Heat</td>
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<td>Sound</td>
<td>4</td>
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<tr>
<td>Magnetism</td>
<td>1</td>
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<tr>
<td>Electricity</td>
<td>-4</td>
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<tr>
<td>Review</td>
<td>--</td>
</tr>
<tr>
<td>All</td>
<td>--</td>
</tr>
</tbody>
</table>

a-Page 27
ranked first. A close relation between time and difficulty should exist—a partial explanation.

Optical instruments, invisible radiations, induced currents, and applications of induced currents, were quite uniformly selected as having the highest degree of difficulty.

The variation in many other divisions was small enough to show rather close correlation of opinion throughout the subject. This table should be of value in selection of time and method for presentation purposes.

Table XII\textsuperscript{a} gives the distribution of those phases of subject matter that could be omitted with least effect on minimum essentials. With the exception of the general field of electricity, there is a high degree of correlation between those subjects of greatest difficulty (Table XI\textsuperscript{b}) and the units that could be omitted. Optical instruments, color, invisible radiations, gas problems, and specific heat seem to be the divisions of subject matter selected in each case. While the range of teacher opinion was large, a number of

\textsuperscript{a} Page 28
\textsuperscript{b} Page 27
TABLE XI

TEACHER'S OPINION OF DEGREE OF DIFFICULTY

<table>
<thead>
<tr>
<th>Subject Matter</th>
<th>School Enrollment</th>
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<td>Density</td>
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<tr>
<td>Force and pressure</td>
<td>3.9</td>
</tr>
<tr>
<td>Pascal's principle</td>
<td>3.5</td>
</tr>
<tr>
<td>Boyle's law</td>
<td>3.6</td>
</tr>
<tr>
<td>Principle of Archimedes</td>
<td>3.8</td>
</tr>
<tr>
<td>Laws of Newton</td>
<td>5.3</td>
</tr>
<tr>
<td>Falling bodies</td>
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</tr>
<tr>
<td>Work, power, and energy</td>
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</tr>
<tr>
<td>Machines</td>
<td>4.6</td>
</tr>
<tr>
<td>Gas problems</td>
<td>7.1</td>
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<td>Specific heat</td>
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<td>Expansion</td>
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<tr>
<td>Change of state</td>
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</tr>
<tr>
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<td>5.6</td>
</tr>
<tr>
<td>Mirrors</td>
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<td>Lenses</td>
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<td>Optical instruments</td>
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<tr>
<td>Color</td>
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</tr>
<tr>
<td>Invisible radiations</td>
<td>7.9</td>
</tr>
<tr>
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<tr>
<td>Hygrometry</td>
<td>4.7</td>
</tr>
<tr>
<td>Industrial applications</td>
<td>5.3</td>
</tr>
<tr>
<td>Transference of heat</td>
<td>3.3</td>
</tr>
<tr>
<td>Magnetism</td>
<td>3.4</td>
</tr>
<tr>
<td>Static electricity</td>
<td>5.2</td>
</tr>
<tr>
<td>Current electricity</td>
<td>5.5</td>
</tr>
<tr>
<td>Effects of electricity</td>
<td>5.8</td>
</tr>
<tr>
<td>Electrical laws</td>
<td>6.5</td>
</tr>
<tr>
<td>Induced currents</td>
<td>7.2</td>
</tr>
<tr>
<td>Applications of induced currents</td>
<td>7.1</td>
</tr>
<tr>
<td>Nature and speed of sound</td>
<td>3.4</td>
</tr>
<tr>
<td>Reflection and reinforcement</td>
<td>6.9</td>
</tr>
<tr>
<td>Vibrating strings</td>
<td>5.9</td>
</tr>
</tbody>
</table>
TABLE XII
TEACHER'S OPINION OF SUBJECT MATTER THAT COULD BE OMITTED WITH LEAST EFFECT ON MINIMUM ESSENTIALS

<table>
<thead>
<tr>
<th>Subject Matter</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
</tr>
<tr>
<td>Density</td>
<td></td>
</tr>
<tr>
<td>Force and pressure</td>
<td></td>
</tr>
<tr>
<td>Pascal's principle</td>
<td>1</td>
</tr>
<tr>
<td>Boyle's law</td>
<td>2</td>
</tr>
<tr>
<td>Principle of Archimedes</td>
<td></td>
</tr>
<tr>
<td>Laws of Newton</td>
<td></td>
</tr>
<tr>
<td>Falling bodies</td>
<td>1</td>
</tr>
<tr>
<td>Work, power, and energy</td>
<td></td>
</tr>
<tr>
<td>Machines</td>
<td></td>
</tr>
<tr>
<td>Gas problems</td>
<td>4</td>
</tr>
<tr>
<td>Specific heat</td>
<td>1</td>
</tr>
<tr>
<td>Expansion</td>
<td></td>
</tr>
<tr>
<td>Change of state</td>
<td></td>
</tr>
<tr>
<td>Nature of light</td>
<td>1</td>
</tr>
<tr>
<td>Mirrors</td>
<td>1</td>
</tr>
<tr>
<td>Lenses</td>
<td>6</td>
</tr>
<tr>
<td>Optical instruments</td>
<td>3</td>
</tr>
<tr>
<td>Color</td>
<td>7</td>
</tr>
<tr>
<td>Invisible radiations</td>
<td></td>
</tr>
<tr>
<td>Metric system</td>
<td></td>
</tr>
<tr>
<td>Hygrometry</td>
<td>2</td>
</tr>
<tr>
<td>Industrial applications</td>
<td>1</td>
</tr>
<tr>
<td>Transference of heat</td>
<td></td>
</tr>
<tr>
<td>Magnetism</td>
<td></td>
</tr>
<tr>
<td>Static electricity</td>
<td>2</td>
</tr>
<tr>
<td>Current electricity</td>
<td></td>
</tr>
<tr>
<td>Effects of electricity</td>
<td>1</td>
</tr>
<tr>
<td>Electrical laws</td>
<td>1</td>
</tr>
<tr>
<td>Induced currents</td>
<td></td>
</tr>
<tr>
<td>Applications of induced currents</td>
<td></td>
</tr>
<tr>
<td>Nature and speed of sound</td>
<td></td>
</tr>
<tr>
<td>Reflection and reinforcement</td>
<td>1</td>
</tr>
<tr>
<td>Vibrating strings</td>
<td></td>
</tr>
<tr>
<td>No omissions</td>
<td>3</td>
</tr>
</tbody>
</table>
divisions of subject matter was suggested as unnecessary by only one or two teachers. The following units would seem necessary in the study of physics; density, force and pressure, Archimede's principle, laws of Newton, work, power, energy, machines, expansion, change of state, metric system, magnetism, current electricity, effects of electricity, and the nature and speed of sound.

Another significant fact revealed by the study shows that out of 154 teachers replying to the questionnaire only 26 favored making no omissions in the subject matter. This would tend to indicate that in the opinion of most science teachers the field of physics as now taught in secondary school is getting too large for a one year subject.

The question of laboratory methods has long been under discussion. Table XIIIa presents a compilation of teacher opinion on the best method of conducting laboratory work for the different phases of subject matter. The results represent the majority of opinions for each division of schools. Some allowance must be made for a change from individual to group experiments in the schools of lesser enrollments because of the

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a. Page 31
amount of apparatus available in some cases. This question was intended to find what experiments, in the opinion of the teacher, could best be used as a project; a teacher demonstration, a group, or an individual undertaking.

Divisions of subject matter selected by teachers of all groups for demonstration work are; Boyle's law, Newton's laws, falling bodies, nature of light, optical instruments, color, invisible radiations, static electricity, and induced currents. An equally large number was selected for individual laboratory work. They are; density, mirrors, metric system, hygrometry, transference of heat, and magnetism. Only one unit was selected for a group experiment—the nature and speed of sound. A further study of Table XIII shows a uniformity of opinion in almost every division of subject matter.

Table XIVa gives a summary of the number and kinds of standard tests given during the past three years. The data of this table shows that ten different tests have been used. The frequency of the use of any one test is small. The Iowa Physics Test, leads having been used by 17 different schools. The Columbia Re-
<table>
<thead>
<tr>
<th>Subject Matter</th>
<th>School Enrollment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
<td>200 to 400</td>
<td>100 to 200</td>
<td>Under 100</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>I, T</td>
<td>I, T</td>
<td>I, T</td>
<td>I, T</td>
<td></td>
</tr>
<tr>
<td>Force and pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pascal's principle</td>
<td>T, P</td>
<td>G, T</td>
<td>T, T</td>
<td>T, T</td>
<td></td>
</tr>
<tr>
<td>Boyle's law</td>
<td>T, I</td>
<td>G, T</td>
<td>T, I</td>
<td>T, I</td>
<td></td>
</tr>
<tr>
<td>Principle of Archimedes</td>
<td>T, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Laws of Newton</td>
<td>T, I</td>
<td>T, T</td>
<td>T, T</td>
<td>T, T</td>
<td></td>
</tr>
<tr>
<td>Falling bodies</td>
<td>T, I</td>
<td>G, T</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Work, power, and energy</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Machines</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Gas problems</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Specific heat</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Expansion</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Change of state</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Nature of light</td>
<td>T, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Mirrors</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Lenses</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Optical instruments</td>
<td>T, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>T, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Invisible radiations</td>
<td>T, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Metric system</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Hygrometry</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Transference of heat</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Magnetism</td>
<td>I, I</td>
<td>G, I</td>
<td>I, G</td>
<td>I, G</td>
<td></td>
</tr>
<tr>
<td>Static electricity</td>
<td>T, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Current electricity</td>
<td>I, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Effects of electricity</td>
<td>I, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Electrical laws</td>
<td>I, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Induced currents</td>
<td>T, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Applications of induced currents</td>
<td>T, I</td>
<td>G, I</td>
<td>T, G</td>
<td>T, G</td>
<td></td>
</tr>
<tr>
<td>Reflection and reinforcement</td>
<td>I, G</td>
<td>G, I</td>
<td>T, T</td>
<td>T, T</td>
<td></td>
</tr>
<tr>
<td>Vibrating strings</td>
<td>I, T</td>
<td>T, T</td>
<td>T, T</td>
<td>T, T</td>
<td></td>
</tr>
</tbody>
</table>

I Individual experiment.  P, Group or individual Project  
T, Teacher demonstration.  G, Groups of two or more.
TABLE XIV

STANDARD TESTS USED DURING PAST 3 YEARS

<table>
<thead>
<tr>
<th>Name of Test</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
</tr>
<tr>
<td>1. Iowa Physics test</td>
<td>4</td>
</tr>
<tr>
<td>2. Hughes Physics scales</td>
<td>1</td>
</tr>
<tr>
<td>3. Thurstone Vocational</td>
<td>2</td>
</tr>
<tr>
<td>Guidance test in Physics</td>
<td></td>
</tr>
<tr>
<td>4. Columbia Research Bureau Physics Test</td>
<td>2</td>
</tr>
<tr>
<td>5. Instructional Tests in Physics by Glenn</td>
<td>3</td>
</tr>
<tr>
<td>6. Emporia Kansas Physics Test</td>
<td>1</td>
</tr>
<tr>
<td>7. Michigan Instructional</td>
<td>1</td>
</tr>
<tr>
<td>8. Oklahoma Comprehensive Objective test</td>
<td>1</td>
</tr>
<tr>
<td>9. Work BOOK tests</td>
<td>-</td>
</tr>
</tbody>
</table>

search Bureau Physics Test, ranks second having been used 14 times. Instructional Tests in Physics by Glenn, and the Emporia Kansas Physics Test, with 12 and 10 users respectively, were the only others mentioned more than a few times.
Examination of Table XIV emphasizes the small total of tests used. Many schools in commenting on this question mentioned lack of funds as a reason for not using standard tests. Disregarding the cause there appears to be a need for improvement in this part of science work in our state.

One of the aims of the supervision of instruction is to secure desired results. To do this an objective must be established. This may be a comparison of work done in other schools or the results of some recognized standard test. Once a standard is selected results may be studied.

TABLE XV

TEACHER OPINION OF PART NEEDED MOST FOR A HIGH SCHOOL SYLLABUS IN SCIENCE

<table>
<thead>
<tr>
<th>Different Suggested Material</th>
<th>School Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above 400</td>
</tr>
<tr>
<td>1. Teacher demonstrations.</td>
<td>4</td>
</tr>
<tr>
<td>2. Difficult problems.</td>
<td>3</td>
</tr>
<tr>
<td>3. Laboratory work.</td>
<td>11</td>
</tr>
<tr>
<td>4. Standard tests.</td>
<td>9</td>
</tr>
<tr>
<td>5. Classroom work.</td>
<td>7</td>
</tr>
</tbody>
</table>

a. Page 32
The purpose of the concluding question of the questionnaire was to secure teachers opinion on the part needed most for a high school syllabus in science. The results are recorded in Table XVa which indicates that 77 teachers favor a needed outline for laboratory work. The need for a standard test in physics was selected by 72 teachers. Next in suggested importance is an outline of special classroom demonstrations to be performed by the teacher was requested by 59 with only 20 asking for the solution of difficult problems.

With a total of 73 standard tests used during the last three years and 72 teachers suggesting a need for tests of this kind in a science syllabus, it would seem that there is a tendency, on the part of many teachers, to improve this phase of science instruction.
COMPARISON OF STATE SYLLABI

In studying available syllabi those states were selected that would have problems similar to those of Nebraska. The syllabi studied were from the states of Minnesota, Kansas, Missouri, and Texas. These states compare favorably in climate, occupations, geographic structure, and population. They would seem to have about the same education problems.

The comparative values of the different syllabi are outlined in Table XVIa which shows the number of pages devoted to physics, the year of publication, and the number of individual experiments suggested. Further analysis shows that two states, Minnesota and Texas, divide the work into units while all states suggest required topics for study. Only one state (Texas) specifies a text book to be used. Missouri is the only state to outline a special description of classroom demonstration. There is no syllabi that gives help on the methods of difficult problem solution while all, with the exception of Minnesota, carefully outlined laboratory work. Models of standard tests are missing from all outlines, while Minnesota devotes considerable space to classroom work with reference to questions, time, and material.

a. Page 37
The following features seemed to be outstanding in the different state syllabi. Minnesota's course of study contained a complete outline of subject matter with a list of essential, optional, and demonstrational experiments. A complete outline of laboratory work was the feature of the Kansas syllabus. Missouri outlined completely a class and laboratory procedure. An example of an individual and a teacher demonstrational experiment was also given. Texas presented a small unit of subject matter with complete laboratory work for the same.

A comparison of the different syllabi would seem to indicate that the greatest emphasis was placed on laboratory work. Admitting the importance of this phase of the subject matter there appears to be a need for improvement in other divisions of the course of study. More uniformity among state syllabi is a problem that suggests investigation.
## TABLE XVI

### COMPARISON OF NEIGHBORING STATE SYLLABI

<table>
<thead>
<tr>
<th>Unit of Comparison</th>
<th>Minn.</th>
<th>Kan.</th>
<th>Mo.</th>
<th>Tex.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Pages for Physics</td>
<td>11,</td>
<td>10,</td>
<td>24,</td>
<td>15</td>
</tr>
<tr>
<td>Date Issued</td>
<td>1925</td>
<td>1925</td>
<td>1927</td>
<td>1924</td>
</tr>
<tr>
<td>No Individual Expr. recommended</td>
<td>40</td>
<td>40</td>
<td>26</td>
<td>36</td>
</tr>
<tr>
<td>Work divided into Units</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Suggested Required Topics</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Text Specified</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Special Descriptions of Classroom Demonstrations</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Methods for Solutions of Difficult Problems</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Outline of Laboratory Work</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Models of Standard Tests</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Outline of Classroom Work with Reference to Questions Material and Time</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
RECENT INVESTIGATIONS

In revising a course of study, the limitations of any single method may be partly overcome by the use of several. This would have a tendency to minimize any short coming of a single investigation and strengthen important phases of subject matter by combining all improvements. Revision by this method would seem to prevent illogical conclusions and support advocated changes. Nearly all recent investigations tend to bring about improvement in the teaching of physics by changing the content and amount of the subject matter or by a closer correlation between classroom and laboratory methods.

The first of the two changes is appropriately expressed by Mulder.¹

¹The issue we wish to raise is as to whether the future texts shall continue to multiply practical applications and illustrations of the principles which have been taught for the last three decades, or shall add, instead, enlightening and coordinating material on the general concepts which come out of the

research of the last twenty-five years; whether new scientific studies of the values of physics shall concentrate on the "practical" uses in the humdrum of life or attempt to discover the ways in which physics may change our thinking about the universe; and at that time devise some method of arriving at the relative importance of these two types of objectives.

Mulder states also that the proper way for rationally determining the subject matter for a course in physics should be:

1. Determine as authoritatively and scientifically as possible the relative importance of those objectives which should govern the choice of subject-matter and method in physics.

This should be done, of course in relation to the general principles of all education, and where possible by objective means.

2. Determine as objectively as possible the specific subject matter materials which will realize these objectives and devise a synthesis of the subject matter elements so obtained.

Work of this kind is being done by several investigators. Durflinger\(^2\) reports that 91

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1. Ibid.
2. G. W. Durflinger, Shall Modern Physics be Included in the High School Course? School Science and Mathematics, XXXII (March 1932), P.328
per cent of high school teachers, replying to a questionnaire, used supplementary physics material in addition to the text book; while only 43.3 per cent reported using all the material of the text book.

An attempt on the part of the Association of Science Teachers of the Middle States and Maryland\(^1\) to secure a revision of the College Entrance Examination Board requirements in physics is another move toward changing the required content of a course in high school physics.

This was attempted as far back as 1920 as indicated in a report\(^2\) of the Sub-committee of the Central Association of Science and Mathematics Teachers, on the content of high school physics.

An investigation by Herriott\(^3\) recommended that physics as now taught should be given primarily to boys. He suggested that the order of weight, emphasis, and treatment of subject matter should be; magnetism and electricity, invisible radiations, mechanics, heat, sound, and light.

\(^1\) Communication read at Eastern Association of Physics Teachers. School Science and Mathematics, XXXII (February 1932), P. 201.

\(^2\) School Science and Mathematics, XXI (March 1921), Pp. 274-279.

\(^3\) M. E. Herriott, Life Activities and the Physics Curriculum. School Science and Mathematics, (June 1924), Pp. 631-634.
Glenn and Brookmeyer\(^1\) made an attempt, in 1922, to select subject matter for a high school physics course from College Entrance Examination question. The investigation showed a trend toward more comprehensive understanding of less material.

Other investigators worked on the values of different types of instruction. Phillips\(^2\) with an experiment to ascertain the relative effectiveness of various types of laboratory instruction reports the individual method of laboratory experiment as having no advantage over the demonstration method in teaching the laws of physics. Cunningham\(^3\) the same year (1920) found the time saved by lecture demonstration to be 30 per cent with a 5 per cent improvement in grades.

In an experiment using three different methods of classroom instruction Hunter\(^4\) found that the

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development method, although taking the most from the teacher, ranked first in immediate retention. The lecture method was second and the textbook method last. He also reported the lecture method to show least recall on material retained.

Kiebler and Woody\textsuperscript{1} in a somewhat similar experiment found the results secured through the use of the demonstrational method were as good, if not better, for immediate and permanent recall, and in the application of knowledge to new problems, than the results from individual laboratory work.

Although investigators have been quite unanimous in concluding that the demonstration method of laboratory work is superior to the individual method, Dowin\textsuperscript{2} points out that the relative merits of the demonstration method have not been established where pupils take the initiative in carrying out the experiment.

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2. Elliot R. Dowin, Shall the Laboratory in the Public Schools be Curtailed. School Science and Mathematics, XXIX (1929), pp. 411-413.
The work of Hurd\(^1\) in establishing complete units of subject matter, is a radical departure from the theoretical textbook procedure. A closer correlation of the unit plan to the conventional method now in use would seem to increase its value. His method of comprehensively testing the results of each unit is a worthwhile contribution to the general reorganization of subject matter in high school physics. To be consistent the results of instruction must be measured in terms of the objectives selected.

The writer believes that a fitting summary of this problem in its present status is given by Obourn\(^2\) when he said:

"There is at present a great need in the field of high school science for objective studies to reveal the things we should teach and then a revamping of our present practice to meet these needs."


Chapter IV

A STANDARD TEST IN HIGH SCHOOL PHYSICS

Teachers usually recognize that examinations have certain advantages and certain disadvantages. An examination encourages or forces the student to review his subjects and he thus gets a broad general view, otherwise usually unobtainable. The student is also given a chance to check up on his mastery of the subject. The teacher is given an insight into his success or failure in imparting knowledge or in stimulating his pupils to acquire knowledge. Among the disadvantages are the generally recognized lack of accurate coordination between a student's actual mastery of the subject and the results of the ordinary type of examination. The examination usually comes at the end of some learning period and brings out a weakness when it is too late to remedy it.

As recently pointed out by Ernest E. Bayles¹, of the University of Kansas, between 85 and 90 per cent of all science teachers' examinations are fact recall type. If emphasis is to be placed on application and comprehension, an examination must be constructed to measure that point. Such a test as that has been prepared,

keeping in mind the aim sought during the period of instruction. Through the solution of new problems it is intended to bring about a minimum of recall with a maximum of application.

The general type of student in schools of our State System, comes from so many different environments and elementary schools, that the problem of individual differences is a serious one. To meet this situation an examination has been constructed which is designed to take care of these differences. The test or series of tests covering mechanics of liquids, mechanics of solids (two), heat (two), light (two), sound, electricity (three), are so constructed that the most brilliant student is adequately tested while there are sufficient easier questions for the others with less ability.

No originality is claimed in designing the test, other than the change in values given to the different questions. This change results in a wide variation of results and simplifies scoring.

CONSTRUCTION OF TEST

A test was arranged and given to eight classes totaling approximately 200 members. The results were then tabulated and arranged in order of their difficulty and the results scored after the rearrangement.
Each of the fifteen questions was given the value of the number of the question, making a total score of 120 possible. The tests for other units were constructed in the same manner. Test for Unit IIa has been given to thirty-six classes, during a period of six years, making a total of 913 taking the test mechanics of fluids.

Another purpose of a test of this kind is to secure a definite mean for a beginning class in physics, in order that the teacher may judge the general knowledge of the group, the effect of different teaching methods on certain units of mastery, and the success or failure of his efforts on certain units of subject matter.

The thirty-six classes taking the test have used five texts: "New Practical Physics," by, Black and Davis; "Physics with Applications" by, Carhart and Chute; "Elements of Physics," by, Millikan and Gale; "Modern Physics," by, Dull; and "The New Physics in Life," by, Henderson. They have had work under three instructors. These classes came at different periods of the day. Now allowance was made for the sex of the individual students as often done in tests of this kind.

An additional object in the construction of this form of test was to compare its results with laws of

probability. This was done by superimposing the frequency of distribution of the test having the greater number of cases (913) on a normal probability curve. The closeness of this relationship made possible the assumption of a normal distribution and a division of the scores into five parts for grading purposes.

The following properties for the test were statistically determined.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>120.</td>
</tr>
<tr>
<td>Mean</td>
<td>57.37</td>
</tr>
<tr>
<td>Median</td>
<td>59.03</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>25.95</td>
</tr>
<tr>
<td>25th percentile or Quartile one</td>
<td>35.34</td>
</tr>
<tr>
<td>75th percentile or Quartile three</td>
<td>74.74</td>
</tr>
<tr>
<td>Quartile Deviation</td>
<td>19.74</td>
</tr>
</tbody>
</table>

The reliability of the mean was found to be .85 which shows that one can be reasonably sure that the true mean lies within the limits 57.267 ± 3 times .85 or between 54.82 and 59.92.

The reliability of the median is .57 which shows that its limits are between 57.32 and 60.74. The reliability of the S.D. is .607 making its limit fall between 24.13 and 27.77, while the limit for the Q.D. was .67.
The closeness with which the test follows the normal probability curve is shown by comparing the measures of central tendencies for the test with those of a true distribution. The true mean and median should be 60 as compared to 57.37 and 59.03 a difference of only 4.3 and 1.4 per cent respectively. Assuming that P.E. = .6745 S.D., there is a difference of 11.0 per cent between the curve values at this point. Values for the other tests\(^1\) fall nearly within these limits.

For the purpose of further study the test was compared with the Oklahoma Comprehensive Objective Test\(^2\) over corresponding material which had a national mean established last year (1931) of 48. Ninety-six comparable cases were used. A correlation of .68 was found between the two tests by the product-moment method with a P.E.\(_r\) = .07. The characteristics of the Oklahoma test for the 96 cases were: mean 47.4, median 46.1, and standard deviation 14.5.

The reliability of the difference between the two means was found to be 5.84 which practically shows complete reliability. The relationship between the two tests is shown graphically by Diagram I\(^a\) which also

---

a. Page 49.
RELATIONSHIP OF TECHNICAL HIGH SCHOOL TEST AND THE OKLAHOMA COMPREHENSIVE OBJECTIVE TEST TO THE STANDARD DEVIATION SCALE FOR 96 COMPARATIVE CASES
converts both scores into standard deviation scale units. This diagram can be used for changing a test score of one test into a corresponding score on the other test or both may be compared in terms of the standard deviation scale.

Tests of this type included in a science syllabus do not necessarily suggest their required adoption. They should become part of a syllabus for those teachers interested in the results of their methods of classroom procedure for the sake of comparison and improvement.
Chapter V

CONCLUSIONS

In view of the general trend toward the construction and submission for adoption of a Science Syllabus, by the High School Section of the Nebraska Academy of Science, this study was made. As stated in Chapter II, the major object of the investigation was to determine whether or not there exists a need for such a course of study. Although the facts observed in this study point to a high degree of standardization among the different schools, with reference to class enrollments, the time spent on different divisions of subject matter and the types of instruction used, the construction of a physics syllabus seems necessary for following reasons:

1. The order of presentation is varied to such an extent that transferring from one school to another, during the school year, is a serious handicap in many cases.

2. Many science teachers believe that too much is being attempted in the field of physics for the time allowed. A selection of subject matter therefore, seems necessary as a means toward a standard minimum high school course in physics.

3. Teacher opinion seems to favor shortening the time spent on the study of light and electric-
ity although these are the divisions of subject matter having the greatest practical development at the present time.

4. The use of established objectives of instruction has been so small that a need for improvement in this field is quite apparent. The fact that 72 teachers suggested standard tests in physics as the most needed part of a Science syllabus emphasizes this.

5. The need for a more complete outline of required objectives in strikingly shown by the correlation of teacher (rationalized) opinion between the degree of difficulty of subject matter and those units of subject matter which they omit; thus causing severe loss of essential objectives to the student.

While a more systematic organization of subject matter is apparently desirable it should be constructed with less emphasis upon college requirements and more stress upon helping the pupil to meet the problems of everyday life. To follow the general changes taking place in our educational systems a greater relationship must exist between the stated aims and actual results of instruction. This requires the teaching of principles instead of facts and a careful testing of the same through the use of objective tests.
To meet the above conditions, the writer submits the following syllabus for use in Nebraska High Schools.

This course of study has been selected and constructed for the following reasons:

I. It is used in the Omaha Technical High School where
   A. A large number of pupils secure nearly all their knowledge of science in high school.
   B. The larger part of each class is composed of students of average intelligence and ability.
   C. College requirements are met for those needing them.
   D. The selection and presentation meets the standards of the North Central Association in:
      1. Selection of subject matter.
      2. Equipment and class room methods.
      3. Length of periods.
      4. Text used.
      5. Laboratory methods.

II. The selection of subject matter aroused interest, by:
   A. Participation in class discussion.
   B. Class demonstrations.
   C. Laboratory methods.

III. It teaches pupils to think by:
   A. Increasing the demand for thinking.
   B. Making pupils conscious of a problem.
   C. Applying their personal experiences.
D. Having them select important topics.
E. Suggesting more efficient methods of work.

IV. It is flexible in selection and provides:
A. For the careful classification of pupils by means of tests or otherwise.
B. Much opportunity for educational and vocational guidance.
C. Selection of material for less able pupils.
D. Enriched courses for the more able pupils.
E. The acceleration of the more able pupils.
F. Original experiments.
G. Extra-curriculum activities.

V. It furnishes the teacher with an immediately available daily program by:
A. Outlining individual laboratory equipment and experiments.
B. Suggesting demonstrational experiments.
C. Providing testing material.
D. Furnishing a complete outline of subject matter.
BIBLIOGRAPHY

BOOKS


Contains a discussion of the problems in curriculum construction setting forth the theory and the relation importance of the major educational objects.


Offers many suggestions for the learner in studying science.


A complete treatment of the statistics necessary for educational measurements.

Good, Carter V., How To Do Research in Education. Baltimore; Warwick and York, Inc. 1929, 298 pp.

A complete handbook on the technique of educational research.


A new viewpoint for the teaching of science.


Much information given on the preparation and use of the questionnaire.

Discusses the teaching of all the important secondary subjects with such high school problems that are common to these subjects.


A source book for information on the correct form for writing a thesis.


A complete volume on the organization and presentation of high school physics. Many difficult phases of teaching subject matter explained.


Gives some good common sense ideas on the organization, arrangement and methods for conducting classes in high school physics.

MAGAZINES


A paper read before the Department of Science Instruction of the N.E.A., at Los Angeles, Calif. June 29, 1931. Worth Reading.


A report on the Physics Section of the Thirty-first annual meeting of the Central Association of Science and Mathematics Teachers, Inc.
Croxton, W. C., Shall Laboratory Work in the Public Schools be Curtailed? School Science and Mathematics, January 1929, XXIX, pp. 79-83.

A general discussion on different methods of laboratory procedure with a review of recent investigations in that field.


An experiment to determine if the extra time spent in individual laboratory work, is more economically, from the standpoint of results, than the lecture demonstration.

Dowing, Elliot R., Shall the Laboratory Work in the public schools be Curtailed? School Science and Mathematics, April 1929, XXIX, pp. 411-413.

A discussion on the relative merits of the demonstration and the individual laboratory method in Science.


A comment on the action of the Wisconsin State Teachers Association, in appointing a committee to study the status of Science teaching in that state.


An attempt to select subject matter for a course in High School Physics from College Entrance Examinations.
Guenther, J. J., Paper read before the High School Section of the Nebraska Academy of Science, May 1931.

A report on the operation and results of the committee appointed to study the proposed construction of a Science Syllabus for Nebraska.


A problem to determine the extent to which activities involving elements of physics are carried on by various groups in every day life.


An experiment to determine the development of power as revealed by the pupils' ability to answer questions after using the developmental method, lecture method, and the textbook method.


A discussion on the experimental use of teaching units in Physical Science.


An experiment conducted with two equated groups on the values of the individual laboratory method and the demonstration laboratory method.


A discussion on the place and purpose of subject matter in teaching physics.

An experiment to ascertain the relative effectiveness of various types of laboratory instruction, as shown by pupils' recollection of experiments performed several months before.


A communication received from the Association of Science Teachers of the Middle States and Maryland asking for revision of the College Entrance Examination in Physics.


Contains a complete outline for physics from the point of view of life situations.

MONOGRAPHS


A very complete survey of secondary education made from a study of fifteen comparative cities.
APPENDIX
## APPENDIX

### HIGH SCHOOLS HAVING ENROLLMENTS OF 400 AND ABOVE REPLYING TO QUESTIONNAIRE

<table>
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<td>York (St. Ursula's)</td>
<td>Stuart</td>
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<td>Omaha (Brownell Hall)</td>
<td>Alvo</td>
</tr>
<tr>
<td>Davenport</td>
<td>Arapahoe</td>
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</tbody>
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## HIGH SCHOOLS HAVING ENROLLMENTS OF 100 to 200 AND REPLYING TO QUESTIONNAIRE

| Weeping Water | Beaver City | Seward (Concordia Academy) |
| Clarks | Rushville | Stanton |
| Wayne | Plainview | Humboldt |
| Stapleton | Red Cloud | Merna |
| Newcastle | Loup City | Hay Springs |
| Friend | Guide Rock | Scribner |
| Benkelman | Sutton | Louisville |
| Meadow Grove | West Point | Clay Center |
| Lincoln | Elgin | Hartington |
| Hooper | Tilden | Wisner |
| Franklin | Wausa | Hemingford |
| Spencer | Waverly | Clarkson |
| Chappell | Overton | Cambridge |
| Ponca | Allen | Rising City |
| St. Paul | Wakefield | Exeter |
| Orleans | St. Edward | Creighton |
| Genoa | Ogallala | Sutherland |
| Hebron | Table Rocks | Sargent |
| Arcadia | Edgar | Ravenna |
| Randolph | Bloomfield | Minatare |
| Laurel | Wilber | Syracuse |
| Burwell | Verdigre | Fairmont |
| Nelson | Kenesaw | Trenton |
High School Physics

Test No. 2
Mechanics of Solids

By M. E. Hurst
Instructor of Physics
Central High School, Tulsa

To Pupils. This is an objective test in three parts, and is designed to determine how well you have mastered the fundamentals of this part of physics and how well you can make applications of the principles learned. When your teacher tells you to start, turn this page, read the directions carefully, and begin the test. Continue until you have finished all of the parts or until you are told to stop. You will be given forty minutes for the test. Ask no questions after you start and do not turn this page before you are told to do so. Fill in the following blanks:

Name ___________________________ Grade______________
Boy or girl------:_ Age-------years. Date______________
School----------------------- City__________________

<table>
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<th>PART</th>
<th>POSSIBLE SCORE</th>
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<td>III</td>
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Published by Harlow Publishing Company, Oklahoma City
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It is unlawful to copy or reproduce this test or any part of it
A SCIENCE SYLLABUS
FOR THE TEACHING OF
HIGH SCHOOL PHYSICS
IN THE
STATE OF NEBRASKA

****

CONSTRUCTED AS
A RESULT OF A STATE WIDE
SURVEY OF SCIENCE TEACHERS
DURING THE YEARS
1931 AND 1932
<table>
<thead>
<tr>
<th>Section</th>
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<td>2</td>
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<td>General Aims</td>
<td>6</td>
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<td>Immediate Aims</td>
<td>10</td>
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<td>Scholarship Standard</td>
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<td>Units of Instruction</td>
<td>13</td>
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<td>Laboratory Apparatus</td>
<td>114</td>
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<td>Bibliography</td>
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</tbody>
</table>
INTRODUCTION

Physical Science is a necessary and important curriculum subject to aid the educational process of continuing growth in the right direction by:

I. Increasing the appreciation for physical and natural phenomena, by:
   A. More scientific reading.
   B. Explaining a multitude of familiar objects and devices that surround us on every hand.
   C. Acquainting one's self with happenings which we may not have noticed previously.
   D. Interpreting causes.
   E. Increasing a scientific vocabulary.
   F. That increase in interest that comes with knowledge.

II. Developing a further mastery of the fundamental principles in:
   A. Previous necessary subject matter.
   B. Reasoning and planning.
   C. Constructional work.
   D. Physical Laws.

III. Developing correct methods of study by:
   A. Solution of problems.
      1. From test.
      2. Original.
B. Laboratory work.
C. Observation.
D. Selection of correct data.
E. Checking of work.
F. Development of original projects.
G. Co-operation with other students.

IV. Showing the realtions of scientific thought to practical skill by:
A. Studying scientific history.
B. Modern inventions.
C. Studying vocations.
D. Health studies.
E. Civic needs.
F. Modern methods of living.

GENERAL SUGGESTIONS

It is not the purpose of this outline in physics to bring about a radical departure in the matter of presentation, requirements, arrangement, nor in any way suggest requirements for science instruction in physics. The outline is the result of a compilation of opinions from a majority of teachers in the State of Nebraska showing their methods and problems. If it can be found to be helpful to any teacher in the subject, in the arranging of his work or in making the scope of the subject matter more standardized, the
outline's construction will be worth while.

The results of the survey show that nearly all teachers in the state are following a procedure of instruction that is closely guided by good basic text books in the subject. Laboratory work is just as logically outlined and followed where equipment and time permit. A change from this plan would not in itself favor more efficient instruction.

An agreement is needed, however, on necessary content for minimum essentials in a course in high school physics. A readjustment of certain teaching factors with aims toward an adjustment in time and more uniform instruction would be methods toward standardization without endangering the rights of individual teachers or schools.

The following factors, as a result of a state wide survey, were suggested to be needed most for more uniform instruction. They are listed in the order of their suggested importance:

1. Outline of laboratory work with reference to material and time.
2. Models of standard tests with standard scores for comparing work.
3. Outline of classroom work with reference to questions, material, and time.
4. Special descriptions of classroom demonstrations to be performed by the teacher.


To incorporate these best opinions, the subject matter in the course of physics is divided into twelve units. A unit is organized around materials on phenomena, or applications of science principles, instead of principles. The principles are derived as interpretation and understanding is necessary for correlation with other units.

Each unit is selected for a maximum time period of three weeks, thereby allowing for plenty of fluctuation without omitting basic material. Each unit is intended to be complete in itself, but it is necessary in several instances to use more than one unit for a larger division of subject matter. It is not imperative to follow the units in the order named, but the sequence between some automatically arrange them.

The laboratory material in a unit is selected for minimum equipment. A selection is suggested but arrangement is in order of the classroom material. Those experiments better adapted for classroom demonstration are so placed in the outline with special description where necessary or helpful. The outline of subject matter is constructed to make easy its
adoption in question form if it is desired to follow it that closely. Where the solution of a difficult problem can be aided by special methods such as a diagram or graphic solution it is also included. Each unit contains also a model of a standard test in problem solution. The test is selected to show the basic type of problem used in the unit. It can be used by those wishing, as a check on accomplishment or comparison.

There are several good tests on the market that can be used but the one accompanying each unit has been selected for the following reasons:

1--The range of difficulty.
2--The simplicity of scoring and using.
3--The test is for the unit being tested.
4--Test values have been established for approximately 1,000 unselected Nebraska pupils.

The test questions have been arranged in order of their difficulty shown by approximately 200 unselected Nebraska high school pupils. The test is scored according to the number of the problem, making the score range 120. This degree of difficulty seems to offer a solution for individual differences so often encountered by the average test.
Table I shows the summary for each test with reference to number of cases, mean and median score, and the standard deviation.

**TABLE I**

**SUMMARY OF RESULTS**
**FOR THE STANDARD TEST ON EACH UNIT**

<table>
<thead>
<tr>
<th>Text for Unit No.</th>
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<th>Median Score</th>
<th>Standard Deviation</th>
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<tr>
<td>I^1</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>II</td>
<td>913</td>
<td>57.37</td>
<td>56.32</td>
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<td>238</td>
<td>52.41</td>
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<td>428</td>
<td>61.27</td>
<td>58.34</td>
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<td>V</td>
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<td>58.24</td>
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</table>

1. Short review tests used in this unit.
2. Test being constructed.

**GENERAL AIMS IN FIRST YEAR PHYSICS**

I. Development and application of scientific interests, vision, and understanding.

With the increasing complexity of life situations, interests in various personal experiences no longer play the part they formerly did in science.
More and more of these experiences must be furnished by schools, through contact with material not found in textbooks. Specialization of industries also make this true. With the rapid development in scientific lines the need for aiding interest and understanding is constantly increasing. No other subject in the field of secondary education can offer the opportunity for this development so well as physics.

II. To appreciate properly today's practical world in addition to the study of common physical phenomena the subject matter should be so organized that intelligent interpretation of scientific changes may be correctly acquired. A useful and meaningful vocabulary is indispensable for proper understanding. The accomplishment of this will be aided by the teaching of basic principles with emphasis upon ability to apply rather than too much stress on the practical.

III. Ability to see the relation of physical science to health, disease, and sanitation.

Physics offers wonderful opportunity for the study of the control and detection of disease through the topics of ventilation, heating systems, refrigeration, humidity, and invisible radiations. Never before has as much progress been made in the development of personal hygiene and public sanitation. Further progress
necessitates an increased interest and knowledge along these lines. This opens an often neglected field filled with great possibilities.

IV. To formulate a habit of science reading which should continue to function throughout life.

The approach science has made into the contents of our current literature, whether it be book, magazine, or newspaper, is already of such magnitude as to necessitate a reading knowledge of science. The general trend is more. We must meet this situation.

V. To see the relation and need of physical science in future vocation.

The importance of vocational guidance, in our present economical conditions, adds to the value of this aim. Instruction in High School Physics can add intelligent understanding to a wise selection for a life's work, not only by giving an insight to present situations but through properly aroused interest, develop a desire for certain vocations.

VI. To maintain such a knowledge of subject matter that will be necessary for immediate use.

This is an aim in all subjects. In Physics, in addition to recall of subject matter, methods of interpreting data, observing phenomena, and application, all play a major part. The association of all
phases of scientific knowledge to real situations make a common goal of purposeful activities.

VII. Development of such values that will aid in civic development proper selections and use of current suggestion and ideas.

Intelligent evaluation is always an important factor in civic life. The demand for expert opinion is ever before use. Physics is filled with opportunities for developing this necessary factor in every phase of the subject. Through careful systematic observation in the laboratory, accurate use of figures in the laboratory, accurate use of figures in the solution of problems, or through the knowledge of physical laws, the possibilities for developing the pupils power to form correct judgments, are always present. Improving this power should be one of our foremost aims in High School Physics.
IMMEDIATE AIMS IN FIRST YEARS PHYSICS

I. Ability to use and interpret formulas.
   It is not the purpose to place too much emphasis on mathematical expressions. They are to be used as a convenient method of expressing relationships previously interpreted. The use of the less difficult algebraic expressions are necessary for concise and accurate thinking.

II. Ability in attacking problems developed to such an extent that it will carry over into everyday life.
   The use of such practical problems that always confront a pupil with normal intelligence is an aim in high school physics.

III. Drill in the technique of formulas to make possible the solution of practical problems.
   The solution of enough problems to secure a natural interest in familiar phenomena and develop a method of approach for some future period.

IV. Ability to understand and interpret correctly graphic representation of various laws and data.
   Simple graphic solutions will aid not only in the future interpretation of mathematical data but will make illustrations and diagrams more helpful.

V. Development and emphasis upon the idea of relationship between quantities and inter-dependence of
variables; especially in the work with graphs, formulas and problems.

This is another method of showing the derivation of physical laws and their application. It should aid in a more practical understanding of everyday phenomena.

VI. Knowledge of the laws of physics and an appreciation of the fact that all life is governed by certain fundamental laws.

The establishment of the above relationship rests with the skilled teacher. Only by recalling and connecting them with an orderly set of principles can the pupil gain a real insight to scientific behavior.
SCHOLARSHIP STANDARD

The requirement shall be the attainment of

I. Correct habits of work.
   A. Careful and independent daily preparation.
   B. Careful following of directions for:
      1. Outside preparation.
      2. Class work.
   C. Being equipped daily with needed books, and materials.
      2. Paper and pencil.
   D. Good judgment in the use of time and materials.
   E. Initiative in attacking work.
      1. Be able to read and understand the written experiment.
   F. Accuracy.
      1. In copying exercises and problems.
      2. In making Scientific statements.
      3. In the fundamental operations of Arithmetic and Algebra.
   G. Neatness in prepared work and class work.
   H. Having assigned work in on time.
   I. Initiative in making up work lost by absence.
   J. Constant effort to speak and write good English.
UNITS OF INSTRUCTION

1. Why study Physics?
2. How man makes use of gaseous and liquid pressures.
3. How bodies are affected by the force which act upon them.
4. How work is accomplished.
5. The effect of heat energy.
6. Utilizing and measuring heat energy.
7. Modern illumination.
8. How light is controlled.
9. Sound production and control.
10. Electric phenomena.
12. Important developments and applications of electrical phenomena.
WHY STUDY PHYSICS

The above question is generally the one first asked by the pupil and should therefore be answered in that order. It is not the purpose of this unit to answer directly such a question, but through careful correlation of common physical phenomena to show a need for closer observation and understanding. The study of physics offers better possibilities for using the natural interest of the pupil in this way, than any other subject. With this interest once aroused and properly directed the question will answer itself.

TEXT BOOK REFERENCES
3. Dull, pp. 1-78.
7. Sears, pp. 1-78, 94-103.

DEMONSTRATIONAL EXPERIMENTS
1. Relation between pressure and depth showing the construction and use of a graphic presentation of
a direct proportion.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Measurement and evaluation of length in English and metric system.
3. Value of correct measurement.
4. Use of vernier caliper, or micrometer caliper.

ADDED SUGGESTIONS

The scope of physics has reached such dimensions that to cover adequately the basic divisions, means a well planned program on the part of the teacher. In addition to this care must be taken in directing the immature minds of the pupil through a clear and careful introduction. A good start is always an aid in any undertaking. Without this kind of a beginning many pupils will lose much that is needed for a later understanding of laws and concepts.

The use of many demonstrational pieces of apparatus will be found helpful in this work. Most of properties of matter are easily illustrated with simple apparatus. A dissectable liter block and a meter
stick are useful in visualizing the units in the metric system. Several objects of the same weight are an aid in teaching density. A box, one foot on an edge, will be found valuable in making comparisons with the English system of weights and measures. It will also aid in distinguishing between force and pressure.

Two short tests are included with this unit for the purpose of review and checking instruction. They should be completed in about fifteen minutes each when a good degree of mastery has been obtained.

OUTLINE OF SUBJECT MATTER

I. THE STUDY OF PHYSICS

A. Definition

1. Universal science

2. General principles

3. Aims

4. Distinction between Physics and Chemistry

B. Study of matter and energy.

1. The three states of matter.
   a. Distinction between solids, liquids and gases.
   b. Illustration of one kind of matter in all three states.

1. Ice; water; steam.
c. What does change of state involve?


A'. General.

a. Space and weight-Expr.

b. Extension-need of measurement.

c. Impenetrability-Expr.

d. Inertia-Definition and example.

e. Mass-measure of Inertia.

l. Need of a system of weighing

f. Porosity

1. Definition and example-Expr.

B'. Specific

a. Cohesion and Adhesion.

1. Definition and example-Expr.

b. Tenacity and Tensile strength-Expr.

c. Ductility.

d. Hardness and Brittleness-Expr.

e. Malleability-Example.


A'. Molecular constitution of matter.


B'. Evidence for molecular motions in gases.

a. By the sense of smell.

C'. Physics studies, the molecule as affected by energy. Chemistry studies, its make up and energy content in Chemical changes. Physics and Chemistry interlap. Therefore called "The Physical Sciences."

D'. Diffusion of gases through porous walls.
   a. How molecular velocity determines the rate of diffusion.

E'. Molecular motions in liquids and evaporation.
   a. Evaporation a proof of molecular motion.
   c. How does molecular motion in gases compare with that of liquids.

F'. Molecular motions and diffusion of solids.
   a. Diffusion of lead and gold.
   b. Comparison of the rates of diffusion of gases, liquids and solids.

II. THE STUDY OF MEASUREMENTS.

A. Length.
   1. Origin of length units. English system.
   2. Arbitrarily chosen. Some of the results.
   3. Origin of length units. Metric system.
   4. Relations between the different units of length.
5. A scientific system.

6. Relationship between the different units of length.

B. Comparison of the English and Metric systems.
   1. A Centimeters to inches; inches to centimeters.
   2. Liters to quarts; quarts to liters.
   3. The cubic centimeter of water; the gram of mass.
   4. Grams to pounds; pounds to grams.

C. The standard unit of time.
   1. The second.

D. The three fundamental units.
   1. The centimeter; the gram; the second.
   2. The C. G. S. system.

E. The distinction between mass and weight.
   1. What a spring scale determines.
   2. What a beam balance determines.
      a. Differences in balances; principle the same.
      b. The correct method of weighing with a beam balance.

F. Definition of density.
   1. In units in the English System.
   2. In units in the metric system.

G. Relation between mass, volume, and density.
   1. Equation for density.

H. Definition of specific gravity.
1. How specific gravity is expressed.

2. Distinction between density and specific gravity.
   a. Specific gravity in the metric system; in the English System.

III. THE STUDY OF PRESSURES.

A. Pressure in liquids.

1. Force beneath the surface of a liquid.
   a. The meaning of "a gram of force".
   b. Experimental proof of forces in liquids.
   c. Law of liquid pressure as a result of the above experiment.
   d. Directions in which the force is applied and the magnitude.
   e. Relation of area, height and density to the force.

2. Pressure in liquids.
   a. Physical definition of pressure.
      1. Value of correct definition. "Scientifically Correct".
   b. Force in liquids is liquid pressure.

3. Levels of liquids in connecting vessels.
   a. Experimental proof.
   b. Law deduced as a result of the above experiment.
   c. Distinction between deductive and inductive reasoning.
SECOND WEEK TEST

1. What is the length of the line below, in centimeters? ( ).

2. What is the length of the line, in millimeters? ( ).

3. What is the length of the line, in decimeters? ( ).

4. What is the length of the line, in meters? ( ).

5. What is the length of the line, in inches? (This should be carried out to two decimal places.) ( ).

6. Fifteen cubic centimeters of water at 4° C. would weigh how many grams? ( ).

7. How many milligrams would this water weigh? ( ).

8. How many centigrams would this water weigh? ( ).

9. How many kilograms would this water weigh? ( ).

10. What would be the volume of this water in liters? ( ).

THIRD WEEK TEST

1. Draw a box with a base, 2 cm. by 4 cm., by 10 cm. high.

2. When filled with water what is the total force on the base.

3. The pressure on the bottom is.

4. The total force on the 4 by 10 side is _____.

5. The total force on the 2 by 10 side is _____.

6. Using the 4 by 10 side as a base what is the total force against it? _____.
7. The pressure on this base is __________.

8. Using the 2 by 10 side as a base, the total force on it is ________________.

9. The pressure on this base is ________________.

10. If filled with mercury the box would exert a force of ____________ gms. on any base.
HOW MAN MAKES USE OF GASEOUS AND LIQUID PRESSURE

It is the purpose of this unit to acquaint the pupil more thoroughly with those common applications of pressure with which everyone is more or less familiar. The use of the hydraulic jack or the hydraulic hoist, of the corner filling station, has long been of interest to all. The problems presented by aviation in its mastery of gaseous pressures and buoyancy are no longer confined to engineer. The part of atmospheric pressure in this ever changing era continues to make it more than before an important and interesting study.

TEXT BOOK REFERENCES

1. Black and Davis, pp. 69-129.
7. Sears, pp. 25-89.
DEMONSTRATIONAL EXPERIMENTS

1. Relation between the pressure and volume of a gas at constant temperature, showing the construction and use of graphic presentation of an inverse proportion.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Density of solid heavier than water by principle of Archimedes.
2. Density of solid lighter than water using principle of Archimedes.
3. Density of liquids by one or more methods.
4. Determination of the laboratory gas pressure, both effective and total.
5. Determination of lung pressure using a mercury manometer.
6. Using an aneroid barometer as an altimeter.

ADDED SUGGESTIONS

Several of the more difficult points in this unit may be made clear by a careful demonstrational experiment of Boyle's Law. Many students have trouble with direct and inverse proportion. It may be emphasized here through the construction of a graph and by pointing out future used for it. A distinction between force
and pressure is often necessary. By comparing the room with a large box it can be more readily visualized. Average depth is also more easily explained by this comparison.

A visit to a local power or water plant, or garage will be useful in studying applications of forces in various ways.

OUTLINE OF SUBJECT MATTER

I. HYDRAULIC PRESSURE

A. Pascal's Law.
   1. Experimental proof of Pascal's law.
   2. Why called the "Hydrostatic Paradox?"

B. Multiplication of force by the transmission of pressure by liquids.

C. Commercial application of Pascal's law.
   1. The Hydraulic Press.
      a. How to calculate the resultant force.
      b. The press does not create energy.
      c. The sacrifice of force for speed and speed for force.
      d. The hydraulic elevator becoming obsolete.
         1'. The application determines the value of the principle.
         2'. Changing times require different applications.
D. City water supply.

1. Water main pressure.

2. Why water in mains does not rise as high as the source.

II. BUOYANCY

A. Archimedes' Principle.

1. History of the discovery.
   a. An illustration of the interpretation of everyday happenings.

   a. An immersed body vs. a floating body.

3. Theoretical proof of the principle.
   a. Principles may be proved theoretically and experimentally.
      a'. Theoretical proof may fail experimentally.
      Why?
      b'. Experimental proof the more valuable test.

B. Specific gravity of a heavy solid.

1. Review of distinction between density and specific gravity.

2. How Archimedes' principle explains specific gravity.

C. Specific gravity methods.

1. Solids heavier than water.
a. Insoluble bodies.

b. Soluble bodies.

c. Regular vs. irregular bodies.

2. Solids lighter than water.

a. Why is the actual weight of the sinker ignored?

3. The hydrometer method.

a. How a hydrometer is calibrated.


III. PNEUMATIC PRESSURE

A. Pressure of air.

1. The weight of air.

a. Proof that air has weight.

b. Proof that air exerts pressure.

2. Cause of the rise of liquids in exhausted tubes.

a. History of the discovery of the reason.

1. Results of a false premise.

b. Overthrow of the premise.

1. Torricelli's experiment.

2. Pascal's experiment.

3. The mercurial barometer.

4. The Aneroid barometer.

5. Relation of barometric changes to barometric readings.

a. How storm direction is foretold from barometric
readings.

b. Compressibility of air.

6. Why hollow bodies are not crushed by atmospheric pressure.
   a. Pressure inside and outside.
   b. Tornadoes; expanding gases; etc., destructibility due to uneven or unequalized pressures.

B. Boyle's law.
   1. Experimental proof.
      a. Determination of the altitude.
      b. Density of the atmosphere.

IV. APPLICATIONS

A. The siphon.
   1. Explanation of the action of the siphon.
   2. Relation of density of the liquid to the depth which may be siphoned off.

B. The air pump.
   1. Explanation of the construction and operation of the pump.

C. The compression pump.
   1. Construction and operation.
   2. Commercial form. The automobile pump.
D. The lift pump.

1. Construction and operation.

2. What must be the position of the valve with respect to the surface of the ground water? Why?

E. The force pump.

1. Construction and operation.

F. The Cartesian diver.

1. Construction and operation.


G. The balloon.

1. Construction and operation.

2. Gases used to fill balloons and efficiency of each.

3. Advantages of the Helium filled balloon.

4. The modern Zeppelin.

H. The diving bell.

1. Construction and operation.


3. The filming of under sea pictures.
FOURTH WEEK TEST

1. When water is 200 c. deep its pressure is (     ).

2. When water is 10 ft. deep its pressure is (     ).

3. The above pressure would be increased (     ) times if the liquid were mercury.

4. The two pistons of a hydraulic press have areas of 3 sq. inches and 30 sq. inches. With 15 pounds of force on the smaller piston the larger will lift (     ).

5. What is the pressure on the small piston in No. 4? (     ).

6. What is the pressure on the large piston in No. 4? (     ).

7. The diameters of the pistons of a hydraulic press are 2 inches and 20 inches. A force of 5 pounds on the small will lift (     ) on the larger.

8. An object weighing 100 g. in air and 50 g. under water has what volume (     ).

9. What is the density of the object in No. 8? (     ).

10. What is the specific gravity of the object? (     ).

TEST ON UNIT II (SIXTH WEEK)

1. How many inches equal 1 meter? ______________________

2. How many pounds in 2 kgm. ? ______________________

3. What is the mass of a liter of mercury? ____________

4. Give the value of atmospheric pressure. ______________

5. If a block contains 20 cc and weighs 15 grams, what is the density of the block? ______________

6. If the diameters of two pistons in a hydraulic press are
1 inch and 10 inches, how do their areas of cross section compare?  

7. The water in a standpipe is 10 meters deep. What is the pressure (g./sq. cm.) on the bottom of the tank?  

6. The density of lead is 11.4 g./cc. How many cc. of lead does it take to make a kg. weight?  

9. The barometer reads 27.3 inches. What is its reading in cms.?  

10. A stone weighs 42 grams in air and 25 grams in water. Find its density.  

11. The water in a standpipe is 40 ft. deep. What is the pressure (lbs./sq. ft.) on the bottom of the tank?  

12. A can weighs 190 grams empty, 500 grams when full of water and 613 grams when full of milk. Find the density of milk.  

13. A dam is 50 ft. long and 6 ft. high and water just reaches the top. What is the total force against the side?  

14. The density of stone is 2.5 g./cc. If a stone weighs 480 grams in water, find its weight in air.  

15. If you can lift 156 lbs., how heavy a stone can you lift under alcohol if the specific gravity of the stone is 2.5 and the density of the alcohol is .825 g/cc?
HOW BODIES ARE AFFECTED BY THE
FORCES WHICH ACT UPON THEM

Nearly everyone is familiar with the term force. Methods of applying and measuring forces have however, generally been left to the engineer. Graphically combining and resolving forces by the pupils opens, especially for the boys, a new and interesting field for speculation. The part that forces play in the stability of matter is generally as new as it is interesting. The vocational value of this unit is clearly in evidence.

TEXT BOOK REFERENCES

2. Brownell, pp. 112-184.
3. Dull, pp. 138-204.
7. Sears, pp. 94-117, 137-161

DEMONSTRATIONAL EXPERIMENTS
1. Develop the laws of accelerated motion from an object rolling down an incline.
2. Determine the distance an object will fall in a fractional part of a second and solve for the value of gravity.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Composition of forces.
2. Verify laws of the pendulum.
3. The value of gravity from a simple pendulum.
4. Plot the path of a projectile under the influence of a propelling force and gravity.
5. Determine the velocity of a propelled object.
6. Hooke's law.

ADDED SUGGESTIONS

Much of the difficulty of this unit will be removed through the proper approach. The pupil should have by this time a clear concept of the terms force and mass. The new term acceleration must be carefully introduced. Through the graphic representation of forces the terms balanced and unbalanced forces can be developed and used to avoid much confusion.\(^1\) The results of an unbalanced force or forces (acceleration) can be easily demonstrated and the class deductively derive the laws governing this type of motion. A second experiment\(^2\) to determine the acceleration of a falling body under the influence of gravity (atwood machine)

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1. Rogers D. Rusk, How to Teach Physics. Page 106.
will not only review the work of the previous lesson but be helpfull in deriving the laws for falling bodies. The following problem will correlate nicely with this for laboratory work.

A projectile is fired with a velocity of 144 feet per second and at an angle of 45 degrees to the horizontal. Draw a diagram to show its position at the end of each second. (Use a scale of 4mm. equal 16 feet.) Find (a) the greatest height reached and (b) the horizontal range.

OUTLINE OF SUBJECT MATTER

I. FORCE AND HOW TO ANALYZE IT.

A. Distinction between a gram of mass and a gram of force.
   1. Definition of the gram of mass and the gram of force.
   2. How measured.
   3. The gram of mass constant; the gram of force variant.

B. Graphic representation of force.
   1. Complete description of a force involves three things;
      a. Magnitude.
      b. Direction.
      c. Point of application.
      a'. These characteristics represented by a straight line.
C. Resultant of two forces acting in the same line.
   1. Definition of resultant.
   2. Resultant is either the sum or the difference of the two forces.

D. Equilibrant.
   1. Definition of equilibrant.

E. The resultant of forces acting at an angle.
   1. Rule for finding the resultant. Construction of parallelogram and diagonal.

F. Component of a force.
   1. Definition.

G. Magnitude of the component of a force in a given direction.
   1. Rule for finding the component of the force in a given direction.

H. Component of gravity effective in producing the section of the pendulum.
   1. Application of component forces to pendular motion.

   1. The Einstein Theory plays little part in earthly forces.
   3. The statement of the law.
   4. Variation of the force of gravity with distance above the earth's surface.
J. Center of gravity.

1. Definition.
2. How to locate the center of gravity.
3. Relation to equilibrium.

K. Equilibrium.

1. Definition.
2. Three states of equilibrium.
   a. Stable Equilibrium.
   b. Neutral equilibrium.
   c. Unstable Equilibrium.

II. UNBALANCED FORCES.

A. Uniform Motion. (Balanced)

1. Types
   a. Rectilinear.
   b. Curvilinear.
   c. Simple harmonic motion.
   d. Rotary motion.

B. Accelerated Motion. (Unbalanced)

1. Terms
   a. Velocity = $v$.
   b. Acceleration = $a$.
   c. Total distance = $s$.
   d. Distance the first second = $d$. 
C. Falling Bodies.

1. Galileo's experiments. Early concepts.

2. Proof of Galileo's conclusions.

3. Relation between distance and time of fall.
   a. The total space is the product of the distance fallen the first second and the square of the number of seconds.

4. Relation between velocity and time of fall.
   a. The gain in velocity each second is the same.
   b. The amount of this gain is numerically equal to twice the distance traversed the first second.

5. Equations for falling bodies.
   a. \( v = at \).
   b. \( s = \frac{1}{2} at^2 \).
   c. \( v = \sqrt{2as} \)

6. Acceleration of a freely falling body.
   a. Acceleration of gravity denoted by \( g \).
   b. \( v = gt; s = \frac{1}{2} gt^2; v = \sqrt{2gs} \)

7. Path of a projectile.
   a. Relation of distance traversed to gravitational pull.

III. LAWS OF MOTION.

A. First law ----- inertia. (Newton's).
1. Definition of inertia.

2. Experiments with inertia.
   a. Centrifuge.
   b. Bodies in motion.
   c. Deviation of path of motion.

3. Illustrations of inertia in every day life.
   a. Car rounding curve.
   b. Sudden stops and starts.

4. Momentum.
   a. Relation of speed and mass to force.

B. Second law of Newton's.

C. Third law of Newton's.

   1. The dyne.
   2. Relation of gram of force to the dyne.

D. Algebraic statement of the second law.

   1. How deduced.

       a. \( F = ma \).

IV. MOLECULAR FORCES.

A. Molecular forces in solids.

   1. Review Kinetic theory.

   2. Elasticity.

       a. Steel is more elastic than rubber. Why?

       b. Limits of perfect elasticity.
a'. Why stress the idea of an elastic limit?.

3. Cohesion and adhesion.

B. Molecular forces in liquids.

1. Experimental proof of the existence of molecular forces in liquids.

2. Shape assumed by a free liquid.

a. Application to commercial manufacture of shot.

b. Emulsions.

3. Liquid films.

a. Experimental evidence.

b. Explanation of surface tension.

4. Capillary attraction.

a. Experimental evidence.

b. Deduction of laws from experimental evidence.

c. Cause of curvature of a liquid surface in a capillary tube.

d. Explanation of ascension and depression in capillary tubes.

5. Capillarity in everyday life.

a. Oil wicks.
b. Dust mulch.
c. Irrigation.
d. Road construction.
e. Blotting paper.

6. Floating of small objects on water.
   b. Destruction or weakening of surface film.
      a’. Addition of alcohol, acids, alkalies, etc.

C. Absorption of gases by solids and liquids.
   1. Experimental proof of absorption of gases by solids.
   2. Experimental proof of absorption of gases in liquids.
      a. Applications in war and peace.
         a’. Gas masks.
            1. War.
            2. Firemen.
            3. Police.
         b’. Carbonated beverages.
         c’. Natural waters containing gases.
            1. Sulphur springs; etc.
   3. Relation of pressure to absorption.
      a. Experimental proof.
      b. Henry’s law.
Indicate all your work between questions

1. The principle of Pascal is illustrated by what machine?

2. Find the weight of a liter of gasoline whose density is .69 g/cc.

3. Name and illustrate each of the three states of equilibrium.

4. A block of wood floats 2/3 submerged and displaces 30 lbs. of water. How much does the block weigh in air?

5. A metal of 6.8 g/cc density is placed in mercury. What fractional part of the iron is submerged?

6. A cylindrical tank 2 m. in diameter and 3 meters deep holds how many kilograms of water?

7. Pistons of a hydraulic press are 2 cm. and 20 cm. in diameter. What force on the small piston is necessary to exert a force of 900 lbs. on the large piston?

8. Draw a diagram of a force pump (a) on the upstroke; (b) on the down stroke, showing action of the valves.

9. How long does it take a body to fall 256 feet?

10. Find the resultant of two component forces of 12 lbs. and 16 lbs. acting at right angles to each other.

11. Calculate the height of a glycerine (D=1.26 b/cc) column that can be supported by atmospheric pressure at sea level.

12. A box 6 cm. long, 5 cm. wide, and 4 cm. deep is filled with mercury. Find the total force exerted against the sides of the box.

13. A liter of air at 70 cm. pressure will require what pressure to compress it to 600 cc?
14. Resolve a force of 120 cc. into a vertical and a horizontal component, one of the components to be three times as large as the other.

15. The period of a pendulum 225. cm. long is ________________.
HOW WORK IS ACCOMPLISHED

Work and machines are generally closely allied in the minds of the pupil. The new concept that work necessitates two things, force and space, brings forth a new understanding of the principles of machines. The several purposes for which a machine can be used is readily explained by a study of the basic principle of work. This principle well mastered can be applied to all machines with advantage to time and understanding.

TEXT BOOK REFERENCES

2. Brownell, pp. 185-222.
7. Sears, pp. 104-162.

DEMONSTRATIONAL EXPERIMENTS

1. Determine the mechanical advantage and efficiency of some type of machine using the principle of work to develop the information. Use a real machine if possible.
SUGGESTED INDIVIDUAL EXPERIMENTS

1. The pulley.
2. Laws of the lever.
3. The inclined plane.
4. The wheel and axle.
5. Sliding friction.
6. Efficiency of commercial block and tackle or some other type of machine.

ADDED SUGGESTIONS

This unit is interesting because of the common knowledge already possessed by the pupils. If time permits, after the basic laws of machines (input equals output) have been studied, a special assignment in the form of a project, to explain and demonstrate different types of machines will be found valuable.

A visit to a local machine shop or garage is an excellent method for becoming familiar with different types of machines.

Measuring the slope of a hill or sidewalk is an interesting project. If you time a pupil in climbing the incline and compute the horse power necessary, it brings out a practical application for machines.
OUTLINE OF SUBJECT MATTER

I. WORK

A. Definition of work.
   1. Review of idea of sacrifice of force for speed.
   2. Units in which work is expressed.
      a. The gram centimeter.
      b. The kilogram meter.
      c. The feet pound.

II. POWER AND ENERGY.

A. Definition of power.
   1. Horse power.
   2. The kilowatt.

B. Definition of energy.
   1. Potential energy.
   2. Kinetic energy.
   3. Transformation of potential and kinetic energy.
      a. Examples of potential energy transformed to kinetic.
      b. Examples of kinetic energy transformed to potential.

III. MACHINES.

A. General law of machines.
   1. Effort times space equals resistance times space.
      (Work equals work).
B. Mechanical advantage of machines.

1. Experimental evidence.
2. Resistance divided by effort.
3. Effort distance divided by resistance distance.

C. Efficiency of machines.

1. Output divided by input.

IV. WORK AND MACHINES.

A. The pulley.

1. The single fixed pulley.
   a. Experimental evidence.
   b. Deduction of equation from above evidence.
   c. Effect of friction on theoretical value.
   d. Emphasis upon the fact that friction plays an important part in the efficiency of any machine.

   Explain value of oil film in elimination of friction.

2. The single movable pulley.
   a. Experimental evidence.
   b. Deduction of equation from above evidence.

3. Combinations of pulleys.
   a. Experimental evidence.
   b. Deduction of equation from such evidence.
   c. Friction increases as pulley number increases.

B. The lever.
1. Simple lever.
   a. Experimental evidence.
   b. Deduction of the law of the lever.
   c. Frictional value very low. Why?

2. The couple.
   a. Lever forces producing rotation.

3. Classes of levers.
   a. Examples of each class.
   b. Advantages and disadvantages of each class.

C. The wheel and axle.
   1. Experimental evidence.
   2. Deduction of the equation from the evidence.
   3. Applications of the wheel and axle to industry.

D. The inclined plane.
   1. Experimental evidence.
   2. Deduction of the equation from the evidence.
   3. Applications to industry.

E. Combinations of the simple machines.
   1. Machinery in general a combination of the six simple machines.
   2. The train of gear wheels.
      a. Force sacrificed for speed.
      b. Speed sacrificed for force.
3. The worm gear.
   a. Speed sacrificed for force.

4. The differential pulley.
   a. Construction and operation.
   b. Speed sacrificed for force.

V. WORK AND HEAT ENERGY.

A. Friction.
   1. Friction always results in wasted work.
   2. Coefficient of friction.
   3. Rolling friction.
   4. Fluid friction.

B. Efficiency.
   1. Definition of efficiency.
   2. Calculation of efficiency.
   3. Efficiency of various machines.
      a. Lever.
      e. Inclined plane.
      b. Pulley systems.
      f. Jack Screw.
      c. Gear Wheels.
      g. Overshot water wheels.
      d. Undershot water wheels.
      h. Water turbines.

C. Mechanical equivalent of heat.
   1. What becomes of wasted work?
      a. Friction produces heat. Can heat produce energy?
1. State and give an example of one of Newton's laws of motion.

2. Write two formulas learned from falling bodies and explain them.

3. Give an example illustrating the three states of equilibrium.

4. A tank is 10ft. long, 8 ft. wide, and 5 ft. deep. How many pounds of water can it hold?

5. Illustrate some type of machine and tell how you would determine the mechanical advantage.

6. A body weighs 400 gms. in air and 300 gms. in water. Find its density. Its volume.

7. The same body weighs 318 ms in alcohol. Find the density of alcohol.

8. Find the resultant of two forces acting upon the same point, one of 60 gms. acting easterly and the other of 45 gms. acting northerly.

9. A block of ice measures 15 cm. x 10 cm. x 5 cm. and weighs 685 gms. What is the density of ice?

10. If a boy can exert a force of 100 lb., how heavy a load can he lift with a second-class lever, 12ft. long, if the resistance is placed 3 ft. from the fulcrum?

11. How far does a freely falling body fall during the first one-half second?

12. A steel bar 10 ft. long weighs 300 lb. How much force must a man exert to pick up one end of the bar, if its center of gravity is in the middle?

13. The nut that tightens the handle bars of a bicycle has 10 threads to the inch. A boy uses a wrench 7 in. long to tighten the nut and exerts a force of 40lb. What is the force that actually tightens the nut?

14. A rod 10 ft. long has a diameter of 2 in. It is drawn through a die which reduces its diameter to 1 in. How do their cross-sectional areas compare? Their lengths?
15. A ladder used as a scaffold is 12 ft. long and weighs 100 lb.

Each end is supported by a block and tackle in which 3 strands support the movable block. If the painter, who weighs 168 lb., stands 1 ft. from one block, with what force must he pull to raise that end of the ladder?
THE EFFECT OF HEAT ENERGY

This unit is closely related to the study of the efficiency of machines. The fact that lubrication is necessary for all moving parts to aid in cutting down losses through friction is well known. Methods for measuring this heat energy is now needed. Expansion or contraction due to changes in temperature can easily be used for this purpose. Measurement of this volume change offers much opportunity for the development of laboratory technique.

TEXT BOOK REFERENCES

3. Dull, pp. 251-279.
7. Sears, pp. 238-266.

DEMONSTRATIONAL EXPERIMENTS

1. Relation between volume and temperature changes for
a given quantity of gas, showing the meaning and location of absolute zero.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Temperature conversion graph to show relation between readings on the Centigrade and Fahrenheit scale.
2. Test the fixed points on a thermometer.
3. Determine the linear coefficient of expansion of some metal.
4. Plot the relationship between temperature (absolute) and volume change for a given quantity of gas.
5. Test for the irregular expansion of water.
6. Demonstrate one or more of the three methods of heat transference.

ADDED SUGGESTIONS

This unit is filled with much interesting material that can be demonstrated to advantage by the instructor. Comparing the sensitiveness of a liquid and gas thermometer is useful in studying expansion. Irregular expansion of metals has many applications. The thermostat is easily constructed and has many uses. Illustrating and explaining the construction of a vacuum bottle is an easy and valuable method for reviewing the three methods of heat transference.
I. EXPANSION.

A. Expansion Coefficients.
   1. Definition of temperature.
      a. By sense of touch.
         1. Unreliable. Have pupils touch different substances of the same temperature, and draw conclusions.
      b. By thermometers.
   3. Significance of temperature from the standpoint of the kinetic theory.
      a. Effect of temperature upon molecular velocity.
      a. Centigrade.
      b. Comparison of the Centigrade and Fahrenheit, thermometers.
         1. Freezing points.
         2. Boiling points.
         3. 5/9 Centigrade degree equals 1 degree Fahrenheit.
         4. Low temperatures.
   a. Boyle's law (review).

5. The gas equation.
   a. How to use the gas equation.

II. TRANSFERENCE OF HEAT.

A. Conduction.
      a. Experimental evidence.
   2. Conduction in liquids and gases.
      a. Experimental evidence.
   3. Conductivity and sensation.
   4. The role of air in nonconductors.
   5. The Davy safety lamp.

B. Convection, in liquids.
   1. Experimental evidence.
   2. Wind and ocean currents.

C. Radiation.
   3. The dewar flask, and the thermos bottle.

D. The heating and ventilation of building.
   1. The principle of ventilation.
a. How produced.

B. The expansion of solids.

1. Proof of expansion.
2. Linear coefficients of expansion.
   a. Definition of linear Coefficient.
3. The Compensated pendulum.
4. The compensated balance wheel.
5. The thermostat.

C. The expansion of liquids.

1. Comparison of the expansion of liquids with that of solids.
   a. Application of the method to water.
      1. Determination of the maximum density of water.
      2. The cooling of a lake in winter.
         a. Temperature effects around water bodies.

D. The expansion of gases.

1. Comparison of the expansion of liquids with that of liquids and solids.
2. Methods of measuring the expansion coefficient of a gas.
   a. The gas thermometer.
   b. How absolute zero was determined.
   c. Relation to the expansion of gases.
3. Comparison of gas and mercury thermometer.
1. Underline the substance having the greatest expansion.
   stone  liquid  gas  paper  brass

2. Name the source of all heat energy. ______________________

3. State the relation between a Centigrade degree and a Fahrenheit degree.

4. Show by a drawing the fixed points on the c. and f. scale.

5. What is the lowest temperature possible? ________________

6. Change
   -21 deg. C. to F. ______

   5 deg. F. to C. ______

   77 deg. F. to C. ______

7. Write algebraically the gas equation. ______ = ______.

8. Describe the irregular expansion of water between 0 and 20 degree C.


10. A metal rod 230 cm. long expanded 2.8 mm. on being raised from
    0 deg. C. to 100 deg. C. Find its coefficient of linear expansion.

11. Given a cu. ft. of gas at 30 lbs. pressure and at 0 deg. C.
    If the temperature is increased to 273 deg. C., what must be the
    increase in pressure to keep the volume constant?

12. 300 cc. of gas at 30 deg. C. will require what temperature to
    increase its volume to 400cc. if the pressure is constant.

13. What will be the volume under standard conditions of 1000 cc.
    of air at 27 deg. C. and pressure of 36 cm. of mercury?

14. A liter of gas at a pressure of 20 cm. and 7 deg. C. will have
    what volume at a pressure of 40 cm. and temperature of 27 deg.

15. If the 13 cu. ft. of air at 76 cm. pressure and 20 deg. C.
    weighs one lb., find the weight of 1000 cu. ft. at 30 deg. C.
    and 46 cm. pressure.
UTILIZING AND MEASURING HEAT ENERGY

For those interested in teaching the practical side of physics opportunity is given in this unit. Recent developments in household refrigeration, the automobile engine, and air conditioning for home heating are all results of physical principles. Heat cannot be scientifically used without some knowledge of the quantity required, and the unit of measurement. In making heat measurements, development of care and laboratory technique, are two of the necessary requirements.

TEXT BOOK REFERENCES

7. Sears, pp. 267-313.

DEMONSTRATIONAL EXPERIMENTS

1. Relation between boiling temperature and pressure.
2. Factors affecting evaporation.
3. Freezing by evaporation (Cryophorus).

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Exchange of heat upon mixing two quantities of water at different temperatures.
2. Specific heat of some metal.
3. Plot the cooling curve of a crystalline substance during the solidification.
4. Determine the heat of fusion for ice.
5. Determine the dew point and relative humidity of the classroom.
6. Find the heat of condensation for steam.

ADDED SUGGESTIONS

A discussion of the heating values of different kinds of fuel is generally an interesting way for introducing heat units. A clearer conception of these units can be established by individual laboratory work. The determination of specific heat, heat of fusion or heat of vaporization, are all valuable for careful laboratory procedure. Much teaching time can be saved by placing working models of different types of engines, or parts of engines, in the laboratory for examination. A visit to an artificial ice plant (if available) or
viewing a demonstrational model of a household refrigerator, will add much interest to this phase of the work. Experiments with dry ice (CO₂) can be used to advantage and will be found interesting.

OUTLINE OF SUBJECT MATTER

I. UNITS OF HEAT
   A. The calorie.
      1. Value of the calorie.
   B. The British Thermal Unit.
      1. Value of the B. T. U.
   C. Measurement of frictional heat.
      1. Joules experiment and results.
   D. Measurement of heat produced by collision.
      1. Joules experiment and results.
   E. Measurement of heat produced by compression.
      1. Joules experiments and results.
   F. Significance of Joules experiments.
      1. Conclusions.
   G. The law of Conservation of Energy.
   H. Perpetual Energy.
      Why impossible?
      2. Energy transformations in a power plant.
   I. Specific Heat.
1. Definition.

   a. By the method of mixtures.

II. USES OF HEAT

A. Change of State.

1. Fusion.
   a. Heat of fusion.
      1'. Means of determining the heat of fusion.
         a'. 80. calories for ice.
      b. Energy transformation in fusion.
         1'. Change of state.
            a'. Solid to liquid.
      c. Heat given out when water freezes.
         1'. Obeys law of conservation of energy.
      2'. Applications of energy transformations, in melting and freezing.
         a'. Refrigeration.

   d. Melting points of crystalline substances.
      1. Laws of melting points of crystalline substances.
      e. Fusion of noncrystalline, or amorphous, substances.
         1. No definite melting point.

      f. Change of volume on solidifying.
         1. Some substance expand.
            a. Water
b. Antimony.
c. Cast iron.
d. Some alloys containing antimony and bismuth.


3. Effects of expansion of water on freezing.
   a. Weathering; rock disintegration.
   b. Ice floats on water because of lesser density.

g. Pressure lowers the melting point of substances which expand on solidifying.

1. Regelation.

2. Evaporation and the Properties of vapors.
   a. Evaporation and temperature.
      l'. Heat an aid to evaporation. Furnishes kinetic energy.
   b. Evaporation of solids—sublimation.
      l'. Experimental evidence.
         a'. Density governed by temperature.
         b'. Exerts pressure.
   c. Influence of air on evaporation.
      l'. Retards evaporation.
         a'. Explained by the kinetic theory.

3. Hygrometry, the study of moisture conditions in the atmosphere.
   a. Condensation of water vapor from the air.
1'. Why the air does not become saturated.
b. Formation of dew and frost.
c. Formation of fog.
d. Formation of clouds, rain, sleet, hail, and snow.
e. The dew point.
   1'. Experimental determination.
f. Humidity of the atmosphere.
   1'. Definition of humidity.
   2'. Definition of relative humidity.
   3. Experimental determination of relative humidity.
      a'. Practical value of humidity determinations.
g. Cooling effect of evaporation.
   1'. Experimental determination.
   2'. Explanation of the cooling effect of evaporation.
h. Freezing by evaporation.
i. Effect of air currents upon evaporation.
   1'. Experimental evidence.
j. The wet and dry bulb hygrometer.
   1'. Construction and operation.
k. Effect of increased surface on evaporation.
1. Summary of Factors Effecting evaporation.

   a. Heat of vaporization defined.
   b. Heat due to condensation.
      1'. Why is a steam burn worse than a boiling water burn?
   d. Boiling temperature defined.
   e. Effect of pressure upon the boiling point.
      1'. Experimental determination.
      2'. Temperature of water boiling on mountains.
      3'. Temperature of water in steam boilers.
      4'. Operation of the Pressure Cooker.
   f. Evaporation and boiling.
   g. Distillation.
      1'. Fractional distillation.

5. Artificial Cooling.
   a. Cooling by solution.
      1. Experimental evidence.
   b. Freezing points of solutions.
      1. Effect of solute upon freezing point of solution.
   c. Freezing mixtures.
III. INDUSTRIAL APPLICATIONS.

A. The modern steam engine.
   1. Explanation of operation from model.

B. Condensing and non-condensing engines.
   1. Engine parts.
   a. The eccentric.
   b. The boiler.
   c. The draft.
   d. The governor.
   2. Compound engines.
   a. Function and operation of cross compound engine cylinders.
   3. Efficiency of steam engines.

C. Principle of the internal-combustion engine.
   1. Experimental evidence.
   2. Operation of the four cycle gas engine.
   3. Operation of the two cycle gas engine.

D. The automobile.
   1. The clutch and transmission.
   2. The differential.
   3. The carburetor.
   4. The ignition.

E. The steam turbine.

F. The principle and operation of the ice machine.
1. Cold storage.

2. Household refrigeration.
   a. Electric.
   b. Gas.

G. Conditioned air.
TEST FOR UNIT

1. What is the temperature of maximum density of water _______? 

2. Locate absolute zero ________________________________________.

3. Write the gas equation ________________________________________.

4. Name three factors affecting evaporation ____________________

5. Write the equation for changing C reading to F reading.

6. If a surveyor's steel tape is exactly 100 ft. long at 20 degrees C., how much too short would it be at 0 degrees C ________?
   \( k = 0.060013 \).

7. How many calories are required to warm a dkg. laundry iron from 20 degrees C. to 130 degrees C if \( K \) equals .113 ____________?

8. If 100 grams of mercury at 95 degrees C are mixed with 100 grams of water at 15 degrees C and the resulting temperature is 17.6 degrees C., what is the specific heat of mercury ____________?

9. How many grams of ice must be put into 200 grams of water @ 40 degrees C to lower the temperature 20 degrees C.? ____________

10. Experiments show that near 100 degrees C. water vapor pressure changes 27mm. for each centigrade degree change in temperature. Find the change in temperature for a change in pressure of 1cm.

11. If the volume of a quantity of air at 30 degrees C. and 76cm. pressure is 500cc., what is the volume at 50 degrees and 70cm. pressure?

12. If the volume of a quantity of air at 20 degrees C. is 200cc., at what temperature will its volume be 400cc.? Pressure remaining constant.

13. If 200 grams of water and 200 grams of iron at 50 degrees C. are mixed with 125 grams of ice, find the resulting temperature if \( K \) equals .11 ____________

14. How much steam must be mixed with 200 grams of ice to make the resulting temperature 50 degrees C.? ____________

15. When 150 grams of copper at 80 degrees C. and 200 grams of iron at 100 degrees C. are dropped into 400 grams of water at 12 degrees contained in a copper calorimeter weighing 50 grams, find the resulting temperature.
   \( K \) for iron equals .113, for copper .095.
MODERN ILLUMINATION

This unit is intended to bring about more universal desire for information on the subject of light. The importance of the study centers on the service our eyes are able to render. Bad lighting generally results in defective sight. The loss of information about things going on around one, is easily realized by closing the eyes for only a few seconds. Harmful and annoying glares are equally noticeable. Knowledge for protecting this most important of all sense organs should be the aim of all.

TEXT BOOK REFERENCES

1. Black and Davis, pp. 492-516, 553-566.

DEMONSTRATIONAL EXPERIMENTS

1. Formation of shadows from wide and point source,
with development into eclipses of sun and moon.

2. The Rumford shadow photometer to show law of light intensity and development of Bunsen photometer.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Locate the image of an object in a plain mirror.
2. Relation of light intensity to distance from source (Bunsen photometer).
3. Show effects of parallel rays striking a concave reflecting surface.
4. Determine the focal length of a concave mirror by several methods.
5. Construction and use of pinhole camera.
6. Construct images of objects placed at different positions in front of concave and convex mirrors, by the ray method.

ADDED SUGGESTIONS

This unit includes many new terms that must be developed carefully to avoid confusion. It also contains considerable simple demonstration material that helps in clarification of these terms. A skilled teacher will find many common interests to use for correlation with other phases of the subject. The efficiency of home lighting, the study of seasons, and
uses made of photometry in industry are but a few of these divisions of subject matter. A few candles, a screen and some other source of light comprise about all the necessary apparatus for many of the experiments.

An electric bell made to vibrate a meter or two of string, will be found valuable in explaining the wave theory of light. Two pieces of plate glass show interference nicely in the presence of colored light.

The formula, \( \text{foot-candles} = \frac{\text{intensity}}{\text{distance}} \text{ squared} \) generally simplifies problems in intensity.

OUTLINE OF SUBJECT MATTER

I. DISTINCTION BETWEEN LIGHT AND SIGHT

   1. The corpuscular theory of light.
   2. The wave theory of light.
      a. Comparison of the two theories.
      b. The process of seeing.
   4. The ether

B. Speed of light.
   1. Roemer. Experiment
   2. Fizeau or Michelson Method

C. Diffusion of light.
   1. What makes objects visible?
   2. Luminous and non-luminous bodies.
a. Modern Illuminants

3. Transparent and opaque bodies.

4. Ray beam, pencil of light. Experiment

5. Shadows, Experiment.
   a. Umbra, Penumbra.
   b. Point source.
   c. Wide source.
   d. Eclipses

   x. of moon, sun.

II. UNITS OF LIGHT MEASUREMENT

A. Intensity of illumination.
   1. Experimental evidence.
   2. The proof of the law of inverse squares.
   3. Photometry

B. Candle power.
   1. Determination with the Bunsen Photometer.

C. Lumen.

D. Foot Candle.

E. Distinction between Foot Candles and candle power.

III. REFLECTING SURFACES

A. Reflection of light.
   1. Experimental evidence.
   2. Laws of reflection.
   3. Light advances in straight lines.
a. The pinhole camera.
b. The eye.

B. Images in mirrors.

1. Construction of image object in a plane mirror.
2. Image of a point in a plane or a curved mirror.
   a. Experimental evidence.
3. Focal length of a curved mirror half its radius of curvature.
4. Image of an object in a convex mirror. 5 positions.
5. Images in concave mirrors.
   a. Use of concave mirrors.
1. Show by drawing, difference between regular and diffused reflection.

2. State law of reflection.

3. What is speed of light?

4. By drawing, show location of image in plane mirror.

5. How do the radius of curvature and focal length of a convex mirror compare?

6. Show by drawing the shadow from point source.

7. Name the two parts of a shadow.

8. Show by drawing the image of an object placed beyond center of curvature in a concave mirror.

9. Show by drawing the shadow from a wide source of light.

10. Make drawing showing an eclipse of the moon.

11. "A" is seated 4 ft. from a lamp; "B" is 5 ft. from the same lamp. Compare the amount of light each receives.

12. An object is placed 15 inches from a concave mirror whose radius of curvature is 12 inches. What is the image distance?

13. The necessary illumination for reading is 3 ft. candles. How far away must a 75 candle-power light be placed?

14. Where must an object be placed to form, in a concave mirror, whose focal length is 12 inches, a real image one half as long as the object?

15. Two lamps, one of 25 candle-power and one of 100 candle-power are 16 feet apart. At what point between the two lamps will the illumination be equal?
HOW LIGHT IS CONTROLLED

The control of light is evidenced in many ways. The camera with its system of lenses, the projection machine, the use of reflector and lens in car lights, are a few light controlling machines. Recent developments in infra-red and ultra-violet rays renew interest in spectrum analysis. The development of such useful instruments, as the telescope and microscope, based upon simple image formation should also be included in this unit. As it answers many questions that already concern the pupils this division of subject matter should be one of interest.

TEXT BOOK REFERENCE

7. Sears, pp. 343-383.
DEMONSTRATIONAL EXPERIMENTS

1. Use an optical disk for showing reflection refraction and total reflection. If carefully adjusted critical angle can be demonstrated and measured.

2. Using sunlight or a source of parallel rays (arc light) show the meaning of beam and pencil of light. Focal length can be easily determined by this method.


SUGGESTED INDIVIDUAL EXPERIMENTS

1. Index of refraction for glass or water.

2. Trace several rays of light through a prism showing total reflection and critical angle.

3. Image formation and determination of focal length of convex lens.

4. Magnifying power of single convex lense.

5. Magnifying power of an astronomical telescope.


ADDED SUGGESTIONS

This unit offers opportunity for plenty construction work in image information and other forms of refraction. This has been found to be one of the best
methods for securing a high degree of mastery on this phase of the work. It develops a useful technique and can be used to derive the lens formula by showing that the curvature of a wave is measured by the reciprocal of the radius. The testing of a camera for focal length and rating of lens is an interesting method for starting the study of optical instruments. The camera can then be used in the development of both telescope and microscope. A careful comparison of the eye and camera will cause renewed interest in both.

OUTLINE OF SUBJECT MATTER

I. REFLECTION.
   A. Law of reflection. Review.
   B. Image formation by mirrors. Review.

II. REFRACTION.
   A. EXPERIMENT evidence
      1. Plate glass experiment.
      2. Water experiment.
   B. Total reflection; critical angle.
      1. Value.
   C. Wave theory explanation of refraction.
   D. Ratio of the speeds of light in air and water.
1. Index of refraction.
2. Value of refraction.

E. Image Formation. (Lenses)
1. Focal length of a convex lens.
2. Conjugate focus.
   a. Formula for conjugate foci.
   b. Virtual image.
   c. Image in concave lens.
3. Formula for:
   a. Lenses.
   b. Sizes of image and object.

F. Optical Instruments.
1. The photographic camera.
2. The projecting lantern.
3. The eye.
   a. Near sightedness.
      1. Cause and cure.
   b. Far sightedness.
      1. Cause and cure.
4. The apparent size of a body.
5. Distance of most distinct vision.
7. Magnifying power of an astronomical telescope.
8. Magnifying power of the compound microscope.
9. The opera glass.
10. The stereoscope.
11. The Zeiss Binocular.
12. The periscope.
13. Parabolic reflectors.

III. DISPERSION.

A. Spectra.

1. The rainbow.
2. Continuous spectra.
3. Bright line spectra.
4. The solar spectrum.
   a. Fraunhofer lines.
5. Doppler’s principle applied to light waves.

B. Color phenomena.

1. Wave lengths of difference colors.
2. Composite nature of white light.
   a. Experimental evidence.
   b. Color of bodies in white lights.
   c. Color of bodies in colored lights.
3. Compound colors.
   a. Experimental evidence.
4. Complimentary colors.
5. Retinal fatigue.
7. Three color printing.
10. Achromatic lenses.

TEST FOR UNIT

1. Show by drawing everything that will happen when an oblique ray of light passes thru a piece of plate glass with parallel sides.
2. A stick 4 feet long casts a shadow 5 feet long. How high is a flag staff which casts a shadow 95 ft. long?
3. Make a drawing showing the path of a ray of light, thru a prism, when the ray is obliquely incident to the face.
4. Will a beam of light going from glass into water be bent toward or away from the perpendicular drawn into the glass?
5. Show by construction the image of an object placed on the principal axis between the focus and twice the focal point, of a double convex lens.
6. Show by drawing an eclipse of the sun.
7. How many images of an object can be seen in two plane mirrors placed at angle of 60 degrees?
8. How fast does light travel in a diamond, Index of refraction is 2.46.
9. How many candles will be required to produce the same intensity of illumination at 3 meters that is produced by 1 candle at 50 cm? Show work.

10. Give two reasons why the sun is visible after it sinks below the horizon.

11. An object is 2 feet from a concave mirror whose focal length is 8 inches. If the object is 1 foot high, how high is the image?

12. A candle is 4 feet from a double convex lens of 16 inches focal length. How far away is the image and what is its size as compared with the object?

13. What effect would immersion in water have upon the focal length of a convex lens?

14. Show by drawing the image of an object placed in front of a convex mirror.

15. The focal length of a double convex lens is 12 inches. Where must the object be placed to get an image of one third the size of the object?
SOUND PRODUCTION AND CONTROL

The importance and necessity for information concerning sound has been greatly increased during the past few years. Talking pictures alone have brought enough problems to the field of sound engineering to make it interesting to everyone. Radio has helped make many terms and principles used in physics familiar. A correlation of recent sound developments with the basic principles involved make this a unit of growing value.

TEXT BOOK REFERENCES

5. Henderson, pp. 597-661.
7. Sears, pp. 201-237.

DEMONSTRATIONAL EXPERIMENTS

1. Relationship of velocity, frequency, and length of wave.
2. Production of sympathetic vibrations and beats, showing their value in tuning musical instruments.

3. The characteristics of a musical tone.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Determine the velocity of sound in air.
2. Find the frequency of a tuning fork.
3. Determine the relation between wave length and length of air column that reinforces it.
4. Study the effect of length and tension upon the rate of vibration of a string.
5. Study the vibrations of a string in segments.
6. Determine the velocity of sound in brass.

ADDED SUGGESTIONS

This unit is filled with interesting demonstrational experiments with only a small amount of equipment necessary. Stress may be placed on the form of wave motion with a two meter spring coil. This coil is also desirable for showing the transverse wave motion of light and radiant heat. Simple apparatus can be constructed for demonstrating beats (two tuning forks of same frequency). A bottle of proper size shows resonance. A sonometer makes a nice project for the manual training department or a small
stringed instrument may be substituted.

The mathematical relationship necessary for pleasing sound combinations with the construction of an octave using triads will bring much interest to the average students. A manometric flame should be included in all laboratory equipment where gas is available.

**OUTLINE OF SUBJECT MATTER**

I. PRODUCTION.

A. Nature and transmission of sound.

1. Sources of sound.
   a. Definition.

2. Media of transmission.
   a. By ordinary matter.

3. Speed of sound transmission.


5. A train of waves; wave length.

6. Relation between velocity, wave length, and number of vibrations per second.

7. Condensations and rarefactions.

8. Distinction between musical sounds and noise.


10. The Doppler effect.

11. Loudness.
II. CONTROL.

A. Reflection, Reenforcement, and interference.

1. Echo.
   a. Sound foci.

2. Resonance.
   a. Experimental evidence.
      1. Best resonant length of a closed pipe is one-fourth wave length.
      2. Best resonant length of an open pipe is one-half wave length.

3. Forced vibrations; sounding boards.

4. Beats.
   a. Experimental evidence.

5. Interference of sound waves by reflection.

B. Properties of Musical Sounds.

1. Physical basis of musical intervals.
   a. Experimental evidence.

2. The major diatonic scale.

3. The even-tempered scale.

C. Vibrating Strings.

1. Laws of vibrating strings.
   a. Experimental evidence.

2. Nodes and loops in vibrating strings.

3. Fundamentals and overtones.
III. Simultaneous production of fundamentals and overtones.

4. Quality.

5. Analysis of tones by the manometric flame.
   a. Experimental evidence.

   a. Experimental evidence.
   b. Production by overtones.

7. Physical significance of harmony and discord.

III. APPLICATION.

A. Wind instruments.
   1. Fundamentals of
      a. Closed pipes.
      b. Open pipes.

B. Stringed instruments.
   1. Laws of vibrating strings.
   2. Different types.

C. Reed instruments.

D. Phonograph.

E. Talking motion pictures.
TEST ON UNIT

1. What causes sound?

2. What is speed of sound in air?

3. State the relation between velocity, wave length, and frequency.

4. Name a second factor necessary for sound.

5. A thunderclap was heard 5.5 seconds after accompanying lightning flash was seen. How far away did the flash occur, if the temperature was 25° C?

6. What factors determine the frequency of a vibrating string?

7. Define a fundamental tone.

8. Two tuning forks, whose frequencies are 435 and 440, when sounded together will produce how many beats per second?

9. Name three characteristics of a musical tone.

10. If one wire has twice the length of another and is stretched by four times the tension, how will their vibration numbers compare?

11. Find the frequency of a note three octaves below a note whose frequency is 264 vibrations per second.

12. The shortest closed air column that gave resonance with a tuning fork was 32 cm. Find the rate of the fork if the velocity of sound was 340 meters per second.

13. If C has 300 vibrations per second, how many would F and A have?
14. A fork making 256 vibrations per second is reinforced by a closed tube of hydrogen 4 feet long. Find the velocity of sound in hydrogen.

15. What is the frequency of the fourth overtone of C on the physical scale?
ELECTRICAL PHENOMENA

The introduction of this unit may be partly controlled by its sequence. If it follows sound the action of electrons in vacuum tubes will be sufficient cause for the development and study of electrical charges. Interest in other common frictional phenomena is readily obtainable.

With the election theory in its present form the pupil will find it an aid in explaining many things that before remained a mystery. The arrangement of elections in the known elements is a valuable reference to the study of chemistry. With logical reasoning the pupil can develop the relationship of an electric charge, a current of electricity, and the resulting magnetic effect. The energy necessary for moving the electrons accounts for the heating effect. Reference to the mechanical energy necessary in producing the original charge will aid in reviewing physical principles.

TEXT BOOK REFERENCES

3. Dull, pp. 500-556, 559-569.
5. Henderson, pp. 365-413.
7. Sears, pp. 348-409.

DEMONSTRATIONAL EXPERIMENTS

1. Development of electrical charges.
2. Charging an electroscope by conduction and induction machine.
3. Factors controlling the capacity of a condenser.
   (a) Static machine        (b) Electrophorus

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Magnetic attraction and repulsion.
2. Relation of molecular arrangement to magnetization.
3. Arrangement and properties of magnetic lines of force.
4. Study the operation of an electric bell.
5. Magnetic effects of an electric current.
6. Study the effect of temperature on resistance.

ADDED SUGGESTIONS

Laboratory work on electrical charges is better
suited for teacher-demonstration than any other part of physics. A teacher should, with proper approach, find little difficulty in developing an interesting introduction to the entire field of electricity. Experimentation on magnetism can be carried on individually with little equipment. The magnetic effect of an electric current can readily be developed by using a compass and a coil of wire containing from one to twenty-five turns. (galvanoscope). Using this coil, a dry cell, and a rheostat to control the current, all the properties of an electromagnet can be shown. If necessary this same coil and compass can be used effectively as a measuring device. It is also useful for determining the polarity of a solenoid. Short circuiting the low voltage output of a bell ringing transformer will demonstrate the heating effect of an electric current.

OUTLINE OF SUBJECT MATTER

I. ELECTRICAL CHARGES.

A. Electrification by friction.
   1. Experimental evidence.
   2. Positive and negative electricity.
   3. The electron theory of electricity.
4. Electrons and electrification.
5. Attraction and repulsion.
   a. Law of charge.
      1'. Kind of charge.
      2'. Distance.
      3'. Medium or dielectric.
B. Controlling the charge.
   1. Charging by conduction.
      a. Electroscope.
      b. Experimental evidence.
   2. Charging by induction.
      a. Experimental evidence.
      b. Signs of the charges.
      c. Amounts of the positive and negative charges.
C. Distribution of the electric charge upon conductors.
   1. Electric charges reside only upon the outside.
      a. Experimental evidence.
      b. Density of the charge.
      c. Conductors and non-conductors.
   2. Electrophorus.
   3. Electric machine.
D. Measurement of electrical charges.
1. Electrical quantities.
   a. One unit of electricity.

2. Electrical pressure or potential.
   a. Electrometer.
   b. Lightning.

3. Electrical capacity.
   a. Condenser.
   b. Leyden jar.
   c. Commercial condensers

II. MAGNETIC EFFECT.

A. Magnetism.

1. Magnets.
   a. Definition.
   b. How identified.
   c. Kinds.
      1. Bar.
      2. Horseshoe.
   d. Poles.

2. The laws of magnetic attraction and repulsion.
   a. Experimental evidence.
   b. Deduction of laws from above experiments.

   a. Bismuth, antimony, etc.

a. Experimental evidence.
b. Principles deduced as a result of experiment.

5. Retentivity and Permeability.
a. Different substances.
   1. Different substances.
      1. Soft iron.
      2. Steel.

a. Experimental evidence.
b. Drawings or blue prints of fields.

7. Fields of force.
a. Definition.
b. Magnetic field of unit strength.

8. Molecular nature of magnetism.
a. Review molecular theory.
b. The molecule the magnetic unit.

a. Molecular rearrangement.
b. Saturation.

10. The earth's magnetism.
a. Location of magnetic poles.

11. Declination.
a. Isogonic lines.

12. The dipping needle.
a. The magnetic equator.

b. Effect of ore bodies.

13. The earth's inductive action.

a. The earth a magnet.

B. Magnetic effects of the current.

1. Shape of the magnetic field about a current.

   a. Experimental evidence.

   b. Ampere's Rule.

2. Loop of wire carrying a current equivalent to a magnet disk.

   a. Experimental evidence.

   b. Rule of the loop carrying a current.

3. Helix carrying a current equivalent to a bar magnet.

   a. Experimental evidence.

   b. The right hand rule applied to coils.

4. The electromagnet.

   a. Construction and operation.

III. HEATING EFFECTS OF ELECTRICAL CURRENTS.

A. Heat developed in a wire by an electric current.

   1. Experimental evidence.

B. Energy relations of the electric current.

   1. The kilowatt hour.

C. Incandescent lamps.

D. The arc lamp.
TEST ON UNIT

1. Body with an excess of electrons has what kind of charge?

2. What kind of charge is repelled by a glass rod which has been rubbed with silk?

3. Which will hold the greater charge, a solid or a hollow sphere of the same diameter?

4. What is the source of the electricity furnished by an electric generator?

5. What is a current of electricity?

6. What name is usually given to electrical pressure?

7. A condenser connected to an electroscope has what effect on the divergence of its leaves for a given charge?

8. What is the best known conductor of electricity?

9. A charges Leyden jar stands on a glass plate. What becomes of its charge when the knob is touched?

10. What kind of charge is always produced by electrostatic induction?

11. The electric whirl illustrates what principle of electricity?

12. The capacity of a condenser depends upon what factors?

13. Make a cross-sectional drawing of a Leyden jar, showing location of the charge.

14. What property of electricity is shown by successive sparks from one charge on a Leyden jar?

15. Make a drawing to illustrate the distribution of a charge (a) on an isolated sphere; (b) on two adjacent spheres; (c) on a body of irregular outline.
MEASURING AND USING ELECTRICITY

This field of electricity contains unusual opportunity for developing laboratory technique in the use and care of electrical instruments. It offers the one chance to make use of city power for lighting and heating purposes.

The construction of different types of electrical circuits by the pupil is an aid in making them familiar with common electrical terms. The proper conception of the correct method for the connecting of different electrical units and controlling the same is the important function of this phase of subject matter.

TEXT BOOK REFERENCES

7. Sears, pp. 429-499.

DEMONSTRATIONAL EXPERIMENTS

1. Construction and use of a voltmeter and ammeter
using two rheostats and some type of galvanometer.

2. Construction and use of a model Wheatstone bridge using five electric lamps.

3. Difference between an A. C. and D. C. generator showing different types of D. C. motors and generators. (Use a dissectable demonstration set or a St. Louis motor).


**SUGGESTED INDIVIDUAL EXPERIMENTS**

1. Study circuits for electric bells, telegraph sounders, and relays.

2. Correct method of using the voltmeter and ammeter.

3. Compare the series and parallel arrangement of circuits.

4. Determine the relation between voltage drop and resistance.

5. Determine the effect of temperature on resistance.

6. Measurement of resistance by either the method of substitution, volt-ammeter method, or the Wheatstone bridge.

7. Study effects of electromagnetic induction and Lenz's law.

3. To study, by means of the St. Louis motor the cause
and direction of rotation, the proper brush position, and its action as a generator.

ADDED SUGGESTIONS

The problem in this unit is generally one of apparatus. Many interesting and valuable aids can be constructed by the pupils with but small cost to the school. A bank of six electric lamps in parallel with one connected in series to the parallel group has many teaching principles. If a little high resistance wire is used in connecting the lamps in parallel, voltage drop is visibly shown by the difference in intensity. An alternating current magnet is easy to construct and demonstrates mutual and self induction as well as Lenz's law. The construction of these teaching helps by the pupil makes a valuable experiment. Parts generally available from obsolete radios make little excuse for a wide awake science teacher to complain of lack of equipment for this phase of subject matter.

OUTLINE FOR UNIT

I. ELECTRICAL UNITS.

A. Measurement of electric currents.

1. The galvanometer.

   a. Construction and operation.
2. The commercial ammeter.
   a. How to connect it up and why.

B. Potential.

1. Potential difference.
   a. Water analogy.

   a. Voltmeter and its construction.

C. Resistance and electromotive force.

1. Electrical resistance.
   a. Experimental evidence.
   b. Law of resistance.
   c. Temperature effects.

2. Electromotive force and its measurement.
   a. Definition of E. M. F.
   b. The electromotive force of galvanic cells.

3. Fall of potential along a conductor.

4. Ohm's law.

5. Internal resistance of a galvanic cell.
   a. Experimental evidence.
   b. Measurement of internal resistance.


7. Joint resistance of conductors connected in series and parallel.
8. Shunts. Their uses.
   a. Wheatstone bridge.

II. APPLICATIONS.

A. Electric bell and telegraph.
   1. The Electric bell.
      a. Construction and operation.
   2. The telegraph.
      a. Principle of the telegraph.
      b. The relay and soundar.

B. Induced currents.
   1. Current induced by a magnet.
      a. Experimental evidence.
      b. Direction of the induced current.
      c. Lenz's law.
      d. Conditions necessary for an induced E. M. F.
   2. The principle of the electric motor.
      a. Experimental evidence.
      b. Principle deduced.
   3. The motor and dynamic rules.
   4. Strength of the induced E. M. F.
   5. Currents induced by rotating coils.

C. Generators.
   1. A simple alternating current generators.
      a. Construction and operation.
b. The multipolar alternator.

c. The principle of the commutator.

2. The drum-armature direct-current dynamo.

3. Dynamo lighting circuit.

4. The electric motor.
   a. Simple electric motor.
   b. Railway motors.
   c. Street car motor.


6. The recording watt-hour motor.

D. Principle of the induction coil and transformer.

1. Currents induced by varying the strength of a magnetic field.
   a. Experimental evidence.
   b. Principle deduced from the above evidence.

2. Direction of the induced current.

3. The E. M. F. of the secondary.


5. The induction coil.
   a. Construction and operation.
   b. Use of the transformer.
   c. Pressure in primary and secondary.
   d. Efficiency.
   e. Commercial transformers.
f. Electrical transmission of power.

6. The tungar rectifier.

7. Principle of the carbon microphone.
   a. Experimental evidence.

8. Principle of the telephone.
   a. Construction and operation.

TEST FOR UNIT

1. Name the units of electrical pressure, current and resistance.

2. What is the hot resistance of a lamp filament which draws 0.22 amperes at 115 volts?

3. What is the cost per hour to operate a radio set using 80 watts of power at 5.8 cents.

4. A flat iron of 22 ohms resistance is used on a 110 volt line for 4 hours. What does it cost at 5.5 cents per kw. hour?

5. Make a diagram showing how the ammeter and voltmeter are properly connected in a circuit.

6. A lamp of 45 ohms resistance is joined in series with a coil of ohms across a 110 volt circuit. What current flows?

7. Give three formulas derived from ohm's law.

8. The resistance of a conductor depends upon what factors?

9. A 32 3. F. lamp takes 0.363 amperes on a 110-volt circuit. What is the efficiency of the lamp in watts per candle power?

10. What resistance must be placed in parallel with a resistance of 4 ohms to make the resistance of the combination 3 ohms?

11. An ammeter of 2.5 ohms is provided with a shunt of 0.5 ohm. If 8 amperes flow in the line, what is the current in the moving coil?
12. Find the combined resistance:

\[ 20 \text{ Ohms} \quad 1.7 \text{ Ohms} \quad 1 \frac{2}{3} \text{ Ohms} \]

\[ 30 \text{ Ohms} \quad 1.3 \text{ Ohms} \]

13. What effects may be produced by a current of electricity?

14. If 1000 feet of no. 16 copper wire which has a resistance of 4 ohms, what will be the resistance of 500 feet of no. 22 copper wire which has half the diameter of the larger one?

15. Find current thru y (a)
   
   Find resistance of x (b)
   
   Find voltage from A to C (c)
IMPORTANT DEVELOPMENTS AND APPLICATIONS
OF ELECTRICAL PHENOMENA

Recent achievements in practical and theoretical physics comprise the major part of this unit. It is constructed toward unification of radiations by starting with the Hertzian wave, with all its applications in radio and television, and comparing it with other types of rays i.e., radium and X ray. This field is being rapidly introduced in all modern texts and is doing much to aid the science teacher in the scientific development of physics. The common usage and value of alternating current has made its study, as a part of physics, a necessity. A failure on the part of the teacher to introduce a pupil to this part of the subject will result in considerable loss of interest.

TEXT BOOK REFERENCES

5. Henderson, pp. 529-596.
7. Sears, pp. 500-559.
DEMONSTRATIONAL EXPERIMENTS

1. Electrical discharge in partial vacua.
2. Sympathetic electrical vibrations (Resonance).
3. High-frequency radiations for a Tesla or Oudin coil.
4. Show the effect of inductance and capacity in an alternating current circuit.

SUGGESTED INDIVIDUAL EXPERIMENTS

1. Voltaic cells.
2. Electrolysis of water.
4. Determine the characteristic of a three-electrode vacuum tube.
5. Determine the meaning and value of power factor.
6. Show the difference between resistance and impedance.
7. Study the fundamental principles of induction motors in two and three phase circuits.

ADDED SUGGESTIONS

Those interested in project work will find opportunity to use it in this unit. Experiments must be selected from available equipment so a large selection was suggested. The experiments in the last unit are more than enough to keep most students busy for the entire time allotted to the study of electricity.
Optional selection by the pupil will motivate interest even to the extent of experimentation at home. The demonstration of some individual experiment before the class has much teaching value. The proper application of laboratory work to this unit will do much in bringing about an interest in physics.

OUTLINE FOR UNIT

I. ELECTRIC MAGNETIC WAVES

A. Hertzian Waves.
   1. Experimental evidence.
      a. High frequency.
   3. Velocity, wave length, and frequency.

B. Applications.
   1. Wireless telegraph.
      a. Transmitter.
      b. Receiving.
   2. Radio.
      a. Kinds of radio waves.
         1. Damped.
         2. Undamped.
         3. Modulated wave train.
      b. Tuning.
1. Inductance.
2. Capacitance.
3. Resonance.
c. Parts of receiving sets.
   1. Radio electron tubes.
      a. Filament.
      b. Grid, its function.
      c. Plate its function.
   2. Grid leak and condenser.
   3. Antenna installation.
   4. Amplification and loud speakers.
   5. A. C. Radio Sets.
d. Television.
   1. Photo-electric cell.
   2. Neon-tube.
   3. Scanning disc.
   e. Talking pictures.

II. ELECTRICAL RADIATIONS.
A. Kinds of radiations.
   1. Introductory evidence.
   2. Geissler tube.
   3. The Crookes tube.
      a. Fluorescent effect.
b. Heating effect.
c. Mechanical effect.
d. Magnetic effect.

5. X Rays.
   a. History.
   b. Properties of X Rays.
      1'. X Ray photographs (radiograph).
      2'. Fluoroscope.
      3'. Use of the X ray.
   c. Coolidge Tube.

B. Radioactive Radiations.
   1. Introductory evidence.
   2. Becquerel rays.
      a. Alpha rays.
      b. Beta ray.
      c. Gamma ray.
   3. Radium.
      a. Madame Curie.
      b. Properties.
         1'. Medical agent.
         2'. Illuminating agent.

III. CHEMICAL EFFECTS OF ELECTRICITY.

A. Primary cells.
   1. Study of the action of a simple cell.
a. Voltaic cell.

b. Local action and amalgamation.

c. Theory of the action of a simple cell.

d. Polarization.
   1'. Its causes.
   2'. Remedies.

e. The Daniel Cell.

f. The Weston normal cell.

g. The Leclanche cell.

h. The dry cell.

2. Combinations of cell.
   a. In series.
   b. In parallel.

B. Secondary Cell.

1. Lead storage batteries.
   a. Construction and operation.
   b. Chemistry involved.

2. Nickel-iron batteries.
   1. The Edison cell.

C. Electrolysis.

1. Electrolysis.
   a. Electrolysis of water experiment.
   b. Electroplating a form of electrolysis.
   c. Electrotyping.
2. Legal units of current and quantity.
   a. Coulomb, the unit of quantity.
   b. Amers, the unit of current.

IV. ALTERNATING CURRENTS.

A. Methods of generating.
   1. Difference between alternating and direct current.
      a. Flow of electrons.
   2. Simple A. C. Generator.
      a. Rotor.
      b. Stator.
   3. Excitation of the magnetic field.
      a. Rotating field magnets.
      b. Separator exciter.
   4. Advantages of alternating current.
      a. Lack of commutators.
      b. Can use transformer.
      c. Economy of transmission.

B. Methods of Controlling Alternating currents.
   1. Voltage and current phases.
      a. Educational terms.
      b. Single phase generator.
      c. Two and three phase generators.
   2. Inductance and Capacitance.
      a. Fixed and variable inductance.
b. Unit of inductance (Henry).

c. Unit of capacity (farad).

1'. Condensers.

a'. Condensers in series.

b'. Condensers in parallel.

d. Effect of inductance in an A. C. circuit.

e. Effect of Capacitance in an A. C. circuit.


a. Watts = Volts x amperes x power factor.

b. Power factor.

C. Alternating Current Motors.

1. Kinds of A. C. Motors.

a. The induction motor.

1'. Single phase.

2'. Their phase.

D. Alternating current measuring instruments.

1. Voltmeter.

2. Ammeter.

3. Wattmeter.

4. Watt-hour meter.

E. The Transformer.

1. Use of the transformer.

2. Types of transformers.

a. Step up.
b. Step down.
c. Open and closed cove type.

F. Rectifiers.

1. Use of rectifier.

2. Types of rectifiers
   a. Electrolytic.
   b. Crystal.
   c. Mercury arc.
   d. Vacuum tube.
   e. Thermionic.
1. To magnetize the eye-end of a needle in order to make it a N-seeking pole, it should be stroked across the __________ pole of a magnet.

2. Underline the substance having the greatest permeability for magnetic lines of force; steel, wood, air, iron, copper.

3. An electric charge changes to an electric current when __________ move.

4. Make a diagram of voltmeter and ammeter in circuit.

5. Make a diagram showing 6 dry cells connected, 3 in series and 2 in parallel.

6. The current in a D. C. circuit varies directly with the _________ and inversely to the _________ This is known as _________ law.

7. What factor enters into the calculation of alternating current power that is not considered in direct current power? _________

8. If a lamp having 45 ohms resistance is joined in series with a coil of 10 ohms across a 110-volt circuit, what is the total resistance of the two pieces? What current flows through the two?
9. What resistance must be placed in parallel with a 4 ohms resistance to make the value of the combination 3 ohms?

10. Find cost of operation for six hours daily for 30 days a radio set drawing 0.5 amps. on a 120 volt circuit at 5 cents per K. W. H.

11. How are X-rays produced?

12. Describe the construction and the operation of a photo electric cell.

13. Make a diagram of an audion radio tube, naming parts.

14. What property of a neon lamp makes it useful in television circuits?

15. What is the nature of each of the emanations from radium?
The frequent changing of science instructors, misplaced, broken, and unfamiliar equipment, are expenses that must be accounted for in every school system. This phase of expenses is doing much to eliminate physics from many places. The time necessary for readjustment of apparatus to make possible the solution of stand-
ard experiments is even a greater loss.

To prevent the growing tendency to reduce individual laboratory work a 'work-box' of equipment is suggested. This box illustrated in Figure I contains all the small apparatus necessary for individually performing the experiments listed in units I, II, III, and IV. Similar boxes for Units V to VIII, and IX to XII are easily constructed.

A well equipped laboratory should contain one box in each group for every two pupils. Some apparatus may be transferred to other boxes if not in use. Use will suggest other additions if necessary.

The catalog cost of equipping a box is about eight dollars which can be greatly reduced by the co-operation of the manual training department. Care of apparatus by this method will almost eliminate loss and breakage while the time saved for the pupil and teacher cannot be estimated. Since suggested laboratory lists can be found in every apparatus catalog, further equipment will not be mentioned.

a. Page 114.
The following equipment is suggested for the different work-boxes.

Box for first four units contains:

1. Lead weight
2. Density bottle
3. Copper cylinder
4. Aluminum cylinder
5. Square of glass
6. Metal disk
7. Porcelain dish
8. Vernier caliper
9. Block of wood (water proof)
10. Cylindrical vessel
11. Foot of rubber tubing
12. Protractor
13. Rulers (metric)

Box for units V to VIII contains:

1. No. 7 Rubber stopper
2. Objects to use in determining specific heat
3. Dew point cup
4. Pinch cocks
5. Calorimeter complete
6. Expansion pointer
7. Bunson burner
8. Short lengths of rubbing tubing
9. Thermometer
10. Compass (pencil)
11. Triangular prisms
12. Light box
13. Rulers (metric)
14. Protractor
15. Plane mirrors
16. Reading glass
17. Light socket and cord for connections
18. Linen tester
Box for the last four units contains:

1 Compass magnetic  
2 Push buttons  
2 Carbon electric lamps  
1 Glass with cover for voltaic cell  
1 Iron filing shaker  
1 Telegraph sounder  
1 Assortment of metals for voltaic cell  
1 Single pole switch  
2 Coils for induction  

1 Rheostat, 6 ohms  
1 Galvansoscope  
1 Horseshoe magnet  
2 Bar magnets  
1 Screw driver  
1 Electric bell  
1 Electric buzzer  
1 Light socket and cord for connections
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COCHRANE, Modern Industrial Progress. J. B. Lippincott.


DARROW, Questions and Problems in Physics. Harcourt, Brace and Co.


DARROW, Masters of Science and Invention. Harcourt, Brace and Co.

DERR, Photography for Students of Physics and Chemistry. The Macmillan Co.

DOLBEAR, Matter, Ether, and Motion. Lothrop, Lee and Shepard, Boston.

KAYE, X Rays. Longmans Green and Co.

KIMBALL, College Physics. Henry Holt and Co.
MANN, Teaching of Physics. The Macmillan Co.
MILLIKAN, Mechanics, Molecular Physics, and Heat. Ginn and Co.
MILLIKAN AND MILLS, Electricity, Sound, and Light. Ginn and Co.
THOMPSON, Light Visible and Invisible. The Macmillan Co.

BULLETINS

ANTI-FRICTION BEARINGS. Hyatt Roller Bearing Co.
Harrison, N. J.

BULLETINS, especially Indandescent Gas Lighting and Inverted Gas Lighting. Welsback Co.
Gloucester, N. J.

BULLETINS, United States Government. Usually 5 or 10 cents each. Circuit Breakers. Roller-Smith Corporation, New York

DELAVAL CREAM SEPARATORS, Dairy Book. The DeLaval Separator Co.

EDISON ALKALINE STORAGE BATTERY. Edison Storage Battery Co., Orange, N. J.

ELECTRIC APPLIANCES. Edison Electric Appliance Co., New York

FRIGIDAIRE. Frigidaire Corporation, Dayton, Ohio.

HOW TO USE A KODAK. Eastman Kodak Co., Rochester, N. Y.
ICELESS REFRIGERATION. Kelvinator Corporation, Detroit, Mich.

LIGHT, ITS USE AND ABUSE. The New York Edison Co., New York

PHOTOGRAPHIC LENSES. Bausch and Lomb Optical Co., Rochester, N. Y.


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TYCOS, Quarterly Magazine. Taylor Instrument Co., Rochester, N. Y.

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