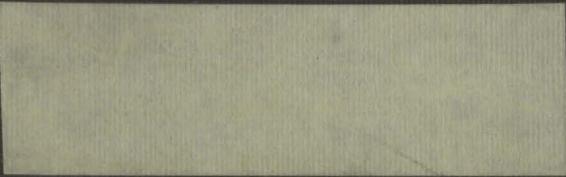


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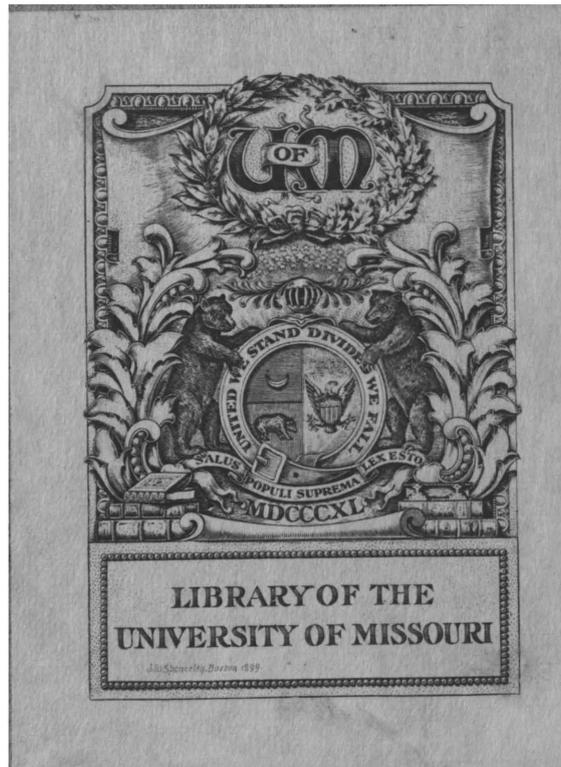
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TENDENCIES TO EMPHASIZE
PRACTICAL PROBLEMS
IN THE
TEACHING OF PHYSICS
IN
SECONDARY SCHOOLS.

by

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SUBMITTED IN PARTIAL FULFILLMENT OF THE
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TABLE OF CONTENTS.

CHAPTER I.

The Development of the Present Unit of Physics

Section I Agitation,	Page 2.
Section II Legislation	9
Section III Execution	26.

CHAPTER II. 40.

Statement of Practical Problems.

CHAPTER III.

General Discussion.

Section I Discussion of the Problems in Chapter II.	47.
Section II Results of Tests and Obser- vations in Class Work.	53.

CHAPTER IV.

Some Conclusions based upon actual Conditions and Problems.	64.
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<i>Bibliography</i>	67.
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PREFACE

The writer of the pages that follow is interested in the phenomena of nature. Nature would teach many lessons to those who are willing to listen. Scientists have felt that some real assistance could be rendered in this instruction and thus the lessons of nature have been supplemented by books. In writing books, authors have emphasized many different features; features which appealed more or less strongly to them. Many times the real lessons were obscured in the attempts to make interpretations. High school physics, no doubt, has often suffered because of failures to get at the appropriate treatment. The hope that something could be contributed for the better appreciation of our physical environment has led the present writer to this study.

For some eight or ten years, the question of things worth while in the physics course of the secondary school, has claimed a share of the writer's thoughts and attention. At the personal suggestion of Dr. J.L. Meriam of the University of Missouri, and under his direction the present paper has been worked out. Many valuable ideas have been gained, by the writer, from actual class work in physics in the University High School 1909-10. Many conclusions reached in the paper are based on considerations of points brought up in connection with this study.

Credit for assistance is due others, who, both by valuable suggestions and encouragement, have contributed much. Not a little help has come from papers and articles published in scientific re-

ports, credit for which is properly acknowledged.

To Dr. O. M. Stewart much credit is due not only for suggestions while the paper was being written, but also for instruction previously given. Very vital assistance was rendered by Dr. E. H. Hall of Harvard and Dr. C. R. Mann of Chicago in letters of advice and counsel.

INTRODUCTION.

.. Perhaps no subject in the secondary school curriculum has greater possibilities than the subject of physics. Most of the sciences are more or less dependent upon it. Not a single one can stand alone. Indeed, approximately every advance in recent times has had its inception in physics. Great advances in lighting systems, wireless telegraphy, aerial navigation, and the methods of transportation of all kinds have been due to physics primarily.

Notwithstanding the great service physics has rendered mankind, we are only beginning to appreciate its possibilities in both content and method. Rich as it is in data, and possessing so much of interest, it will certainly soon occupy its deserved place in the list of secondary school subjects. Many things are responsible for its failure to receive proper recognition commensurate with its importance in the curriculum.

When first introduced, physics was not well organized, and few knew its possibilities. Teachers who were called upon to teach it were incompetent to give creditable instruction. The course then was too bookish and failed to arouse interest as it is calculated to do. Then too, there were the staid language courses with their centuries of learning and prestige. To win a coordinate place was a task of great proportions.

Another thing: to successfully present a physics course worth while, there must be ample laboratory equipment. This was a stumbling block twenty-five years ago, and even is a matter of great concern today. While the teacher was quick to see what was

demanded of him, yet his efficiency was lessened by the lack of laboratory facilities. School communities had to be educated and time was necessary. Along with this failure to furnish laboratory work there was the question of how much time to devote to such work. Beginning with the first account we have of physics as a subject for study in schools, laboratory work has steadily increased in favor.¹ When the course consisted of only two fifteen minute periods per week, no laboratory work at all was thought of. The last two decades have seen laboratory work grow strongly in favor. Through experimental work the student is able to gain a better idea of every day phenomena. The text book assists in this work of arranging physical knowledge. It seems that by properly apportioning the time between the laboratory and the text, we can strike the golden mean. It is a matter of only brief^a period, apparently, until physics will occupy its rightful place in the course of study.

In the chapters that follow, an attempt is made to find in the physics course, evidences of more attention to the specifically concrete and practical.

Chapter I is divided into three sections: Section I gives an account of individual contributions both through scientific literature and committee reports. It is an account of what individual writers have done to change the character of the physics course. Section III traces the matter of development further, and indicates the various organized efforts of scientific bodies and committees. Here we can begin to see something definite. Section III deals

1. Mann C. R. Science 30: 789.

with the representative texts of the past twenty-five or thirty years. A study of the texts is made to see how they have conformed to the growing demands of the times as reflected in association meetings. Some interesting comparisons of the texts involving the number of pages and paragraphs are made. Seventeen well-known High School texts are used in the comparison. The comparisons are intended to show the development of physics as reflected in the text books.

Chapter II contains a list of practical problems of the various general divisions of the subject. They are suggested by actual experiences of the members of the physics classes of the High School 1909-1910. No discussion is given in the chapter. The aim is to give a pretty general list of practical problems. The discussion is deferred to Chapter III.

In Chapter III material obtained by observation in class and by a series of questions and tests is discussed. Some general statements are warranted by the results of tests.

In Chapter IV will be found some conclusions based on actual conditions and problems.

CHAPTER I.

THE DEVELOPMENT OF THE PRESENT UNIT OF
PHYSICS IN SECONDARY SCHOOLS.

Positive action along scientific lines, especially where courses and subject-matter are involved, is taken only after many plans have been proposed and discussed through different scientific publications. Men are freer to express themselves through articles, because it is in the scientific literature of the day that opinions are weighed and ideas compared. Men resort to the press to exploit their theories. They invite criticism and suggestions. After all has been said pro and con, very definite conclusions can be reached and real progress made.

Besides expressing ideas through publications there are the debates and discussions in committees and associations. Here are earnest endeavors to solve the problems of laboratory, text book and laboratory notes. Finally there is an attempt to formulate the ideas and conclusions into motions or resolutions. Great care must be exercised, for whatever passes the conference must be worthy of the dignity and learning of its members.

After definite plans are adopted setting forth the general ideas regarding the character of courses, texts emphasizing different phases of the subject follow. Each writer is influenced more or less by what he considers the more important fundamental principles. The text represents the most concrete statement of the writer's conception of what the course should be. These general

statements may be applied to the usual method of teaching physics. By reason of these considerations, the first chapter is arranged in three sections: Agitation, Legislation, and Execution.

SECTION I.

AGITATION.

In the early part of the nineteenth century, some of the secondary schools introduced science into the curriculum.¹ This was done at the request of the patrons of the schools. While the courses offered were good, there was yet a desire for something practical. To meet this demand, science was added to the list of courses for secondary schools. All branches of science experienced many changes. Physics is typical in this respect.

The question of the character of the course quickly came up. What use shall be made of the laboratory; how should the time be divided between the laboratory exercises. These indicate the character of questions asked. Some physicists believed that the study of physics is not so much for the purpose of acquiring new facts (for the average student has a bountiful supply of facts already) as to train the student in observation and to help him to interpret what he sees and observes.² There were other men who felt that laboratory work was the chief thing in the study of physics. The extreme position that the student should rediscover

1. Mann C. R. Sci. 30: 951.

2. Packard, J. G. (1910) Ed. 30: 512

physical laws was taken by some. The student was set to work in the laboratory, and told to find out things for himself. Only a few such experiences were necessary to show that this was undesirable and wrong. There was soon less emphasis on this kind of laboratory work and the accustomed idea that laboratory work should merely supplement the student's experience. It is practically this idea that prevails today. If the secondary school course in physics is calculated to help the student interpret his physical environment, we can easily see how the laboratory can be of great assistance. The period of time given to laboratory experiments has varied considerably. At times one hour or period per week was considered sufficient. This amount of time varied until in some cases one half of the time was spent in the laboratory. Laboratory work has usually been accepted at one half its time value. The time spent in laboratory work now is from two fifths to one half of entire time.

With the discussions of the reason for laboratory work physicists were also asking how much time should be given to it. So far as it can be ascertained physics was first taught to Harvard freshmen in 1670.⁸ The course consisted of two fifteen minute periods per week with no laboratory work either by the instructor in class demonstrations or by the students themselves. There laboratory work was not considered at all essential in early times. It has generally remained secondary to class room work.

Another question that has received marked attention is whether

3. Mann C.R. Sci. 30: 951.

laboratory work shall be qualitative or quantitative.⁴ There seems to be a very decided difference of opinion on this point. As one says, physics is exact and calls for careful measurements in the laboratory.

Dr. Hall of Harvard gave it as his opinion (1887) that physics should be studied partly for training and partly for information. He considered laboratory work very essential.⁵ Text book physics gives little training that arithmetic, algebra or geometry cannot furnish. When the laboratory method is used in physics teaching, the student gets a kind of training not furnished by any other required subject. When the text book is used exclusively the information obtained is rather indefinite and covers a great range of phenomena. The laboratory work on the other hand, gives less information, but it is more definite. Laboratory gives the student an opportunity to go beyond the covers of his book. Teachers of physics welcomed the advent of experimental work into the physics course, for it seemed to be a solution for the evil practice of cramming to get into college.

Students should, therefore, be required to make all readings of instruments very exact. Another says we are not trying to make specialists out of all. Consequently we should be satisfied with approximate results paying closer attention to the phenomena with their underlying principles.⁶ Franklin (Lehigh U.) a member of the College Entrance Examination Board said in a New Jersey Teacher's meeting: "It is not important that high school physics should be

4. Packard J. C. Ed. 30: 512 (1910).

5. Hall E. H. Sci. 4: 129.

6. Woodhull J.P. Ed. Rev. 13: 236.

quantitative or qualitative, it should be phenomenology.⁷ It is argued that so much time would be consumed in accurate reading of instruments that real valuable work would not be done. To understand principles with their varied applications is of greater value than to measure the diameter of a hair to the thousandth of a millimeter or to determine whether the cross section of a pin is a circle.

How much mathematics to introduce into the secondary school and course in physics is unsettled. Some would emphasize this point,⁸ require a great deal of mathematical work. Much emphasis is laid on accuracy in results and it is often the case that if results vary a small per cent the experiment must be tried a second time. The *consensus* of opinion is that mathematical development should be avoided.⁸ The simpler the mathematical relations, the better for the student. It should be remembered that the subject of physics is not play at best, and that intricate mathematical explanation should be discarded.⁹

Prof. Woodhull (1905) said that the committee appointed to arrange a suitable physics course failed because they were unacquainted with the secondary school.¹⁰ The course planned involved too much mathematics. It is said that a professor of mathematics was willing to accept the course in physics for algebra or plane geometry. In all probability, the public will decide what course

7. J. F. Woodhull Ed. Rev. 13: 236.

8. Woodhull J.F. Ed. Rev. 13: 236.

9. Michelson A.A. School Sci. and Math. (1909) 9:3.

10. Woodhull, J.F. Ed. Rev. 13: 236.

shall be offered in the secondary schools. It has even been intimated that a knowledge of the theorem of the triangle with all its corollaries is sufficient to handle all the geometry that the physics course should involve.¹¹ Only the simplest algebraic processes are essential for mastering it. The mathematical problem for the physics teacher is to teach his students to express in simple mathematical language facts already known to him. Probably from 75% to 90% of the mathematics can be easily eliminated from the elementary physics course.

That physics should be taught from the standpoint of practical application is admitted and even urged by many.¹² It is true that much of the subject-matter of the high school physics course at present has little or no direct connection with the needs of the student. Theories and hypotheses are abundant, and in many cases could probably be omitted. It is not desirable, however, that all such be eliminated for much of the science rests upon them. Little could be done with the subject of light, for instance, if theoretical and hypothetical considerations were abandoned. The student has many questions, the answers to which he would like to know. He can receive valuable suggestions from hypotheses worked out by men who have spent much time on the particular point in question. All the hypothetical statements serve as a working basis. Who does not believe the truth is more evident even though there must necessarily be some readjustment?

11. Millikan, R.A. Sch. Rev. 14:250.

12. Woodhull J.F. Ed. Rev. 13: 236.

Dr. C. R. Mann suggests that the course can be made more practical by eliminating such terms as erg and dyne.¹³ Such terms are for use only when more advanced work is pursued in engineering courses.

We must go back some twenty five years to see why our courses in physics are lacking in practical application.¹⁴ Formerly, the subject of natural philosophy was intimately concerned with familiar phenomena of daily life. The work was largely, if not wholly, quantitative. The idea was to use apparatus and make a show of it. Theories were left to college professors. Their researches and reasoning have led us into deep water. Controversies naturally arose. In order to establish some definite physical proposition, accurate instruments were constructed. Little practical application was ever made, and the would-be student of physics was truly bewildered. Thus, in their earnest attempts to clear up the subject of physics, it appears that less progress has been made than was anticipated.

A final point of discussion is that of the advisability of different physics courses in the High School for boys and girls; also, the advisability of two courses for boys, -one for those preparing for college, and the other for those who are not. Prof. Albright of Columbus Ohio believes in separate courses for boys and girls. He maintains such courses in Columbus High Schools.¹⁵ ~~Some authorities are strictly opposed to separate~~

13. Sch. Sci. Math. 1909.
14. Packard J. C. Ed. 30: 512.
15. Sch. Sci. Math.

courses in either case. It is contended that girls need to interpret their environments just as much as do boys. They are quite as capable. Eliminate 75% of the mathematics from the course and there will be little objection on the part of girls to physics. As to the question of separate courses for the boy who goes to college and the one who does not many contend that there should be separate courses, while others believe in the same course for both. Since the purpose of a course in physics is to enable the student to explain the world in which he finds himself,¹⁶ and not to give information necessarily, there seems to be no valid reason for separate courses. In answer to those who say that there are certain technical formulas and terms which the engineering student needs, we may reply that advanced courses are always necessary and these technical terms can be easily and quickly learned.

16. Committee of Ten Report, 1892.

SECTION II.

LEGISLATION.

When the subject of physics was first introduced, few men had any definite idea of its value and purpose. Then, too, the content of the course had not been carefully considered. Methods for presenting the subject were proposed. As the subject developed, more varied and intricate problems arose. Thus with all the indicated complications, discussions and resolutions came as a natural consequence.

Resolutions and actions of the different scientific associations naturally follow the agitations of their individual members. The basis for legislation consists in conclusions drawn from articles in periodicals, and from decisions reached through discussions of the important questions. Necessarily the character of the resolutions changed with the rapid development of the subject.

The first definitely organized effort in shaping the physics course is found in the entrance requirements of colleges, where certain universities accepted students for admission, they made certain definite regulations. The system of requirements in physics maintained at Harvard in 1886, 1897, and 1909 will be considered briefly.¹ These dates give three different requirements covering a period of some twenty-three years, taken at intervals of about eleven years. In 1886-- Avery's Elements of Natural Philosophy or Gage's Elements of Physics was the required text. A second course consisted of experiments covering the same di-

1. Harvard Entrance Requirements 1886,
Harvard Catalogue, 1886-7.

visions as are recognized today. The subject was usually divided into five sections: Mechanics, sound, light, heat, and electricity. The laboratory work consisted of at least forty experiments, actually performed by the student at school. The experiments were to be selected from Worthington "Laboratory Practice" or from "New Physics" by Trowbridge. Harvard's faculty recommended that the latter course be taken if possible. There was an examination in physics for entrance to college. This examination was to test skill. The original laboratory note book had to be presented, after having been certified to by the teacher. Laboratory work counted one half its face value.

The required texts in 1897 were the same as in 1886. The work required was practically the same in the texts as eleven years before. There was a restriction regarding the laboratory work. The number of experiments again was forty, but these had to be selected from a test issued by the university. This list is known as the "Descriptive List of Elementary Exercises in Physics". The candidate for admission to the college passed the same kind of examinations in the text, and on laboratory work as in 1886. The note book had to contain an index of the exercises described. The university recommended that the laboratory work be accompanied by a course of lectures. If lectures could not be had, then the study of two texts, from different points of view, was recommended.

In 1898 a new definition was formulated. It provided for more qualitative work, and directed attention to the application of principles of physics to everyday life. It was hoped that lab-

oratory work would give practice in observation and explanation of physical phenomena.

Such a course as this is of the greatest value. It is the best preparation for college as well as the best practical training for general culture. The student should not theorize too much in the elementary course in physics. He has previously gathered enough physical facts together, which, if explained and correlated, will form the basis for future study. Such a course should be the means of fixing a considerable variety of facts and principles in the minds of the students. The new definition gave more freedom to the student. It provided for thirty-five experiments out of a list of sixty. The only restrictions were the following: required - mechanics, ten; sound, three; light, three; heat, three; electricity, three. However, any one of the last four may be omitted. The course was thus less restrictive than before. This shows a recognition on the part of the University authorities, of the fact that physics work varies with the school community.

The presentation of the laboratory note books was required that there might be some positive evidence of the student having formed the habit of keeping full and intelligible notes. More weight, however, was given to the laboratory examination than to note books. If taken in the last year of the preparatory school, the course in physics is expected to occupy, in laboratory work, recitations, and lectures, five ordinary periods (fifty minutes) for entire the year. Two laboratory periods per week were considered quite suf-

ficient.

The requirements in physics in Harvard for 1908 differed little from those in 1897. Again qualitative lecture-room experiments emphasizing physical laws found in every day life were advised. Examinations were still required - covering text and laboratory work. Examinations included numerical problems. More questions were asked than anyone candidate was expected to answer. This was done to allow for diversity of instruction in various schools. While Harvard has always required that the laboratory note book be presented, yet there has been a feeling that a certificate from the laboratory instructor was sufficient. Consequently there was passed a motion providing for such a plan. It was argued that it would be far better to take the work of the teacher as to the value of the student's laboratory work, than to depend upon the examiner's report on it, based upon a five minute's examination. This doubtless will simplify matters.

Laboratory work preparing for college should give practice in the observation and explanation of physical phenomena, skill in measurement, and training to the hand. It should also fix well in the student's mind a considerable variety of facts and principles. The same number of exercises (thirty-five out of a list of sixty) is required as in 1897. The laboratory notebook must be presented bearing the indorsement of the instructor. The notebook must be indexed. The laboratory experiments done need not necessarily be the same as those upon which the candidates ask an examination, but should be their equivalent in character and

amount of quantitative work. The length of time, division of time between laboratory and recitation were all the same as in 1897. Two periods per week in laboratory were considered sufficient.

The preceding facts regarding Harvard's entrance requirements in physics are given in order that we may get an idea of the development during the past twenty-five years in one college. It is not too much to say, perhaps, that Harvard and Dr. Hall have had as much to do with shaping the physics course as any other forces. While the colleges did not make the courses and tell high schools they must follow the outline, yet they did so virtually. When the entrance examinations were based on the course outlined the secondary schools would naturally follow it, since their students desired admission. The NATIONAL EDUCATIONAL ASSOCIATION passed resolutions as far back as 1871 regarding physics. While the facts of physics were considered important, yet the primary reason for the introduction of science into the schools is the peculiar mental training it can give. It was thought that trained minds were better able to use facts than the untrained ones. The best course of study, according to the best judgment of the committee, included a course of five hours weekly. It was also agreed that some study of physics should be required for admission to college.²

The NATIONAL EDUCATIONAL ASSOCIATION had much to do in shaping the physics course from time to time.³ It was not, however, till

2. N. E. A. 1871.

3. N. E. A. 1887.

1887 that any definite action was taken regarding the physics unit. Although appointed two years before, the committee had made no definite report. They felt that the teachers of physics should get together and agree upon a group of fundamentals which no course should omit. Experimental work was to be emphasized.

In order that a clear understanding of the course which the committee suggested, may be had, the subjects are here given in brief outline. It will be seen that the same general divisions of the subject prevailed at that time as at present. There has never been much change in the general nature of the course. It is very probable that many more topics will be added. The suggested list is as follows:⁴

Mechanics

- 1 Measure length, volume, and mass.
- 2 Inertia
- 3 Composition of Forces
- 4 Parallel forces
- 5 Center of Gravity
- 6 Simple Machines
- 7 Pendulum
- 8 Centrifugal force
- 9 Buoyancy of liquids
- 10 Density of bodies
- 11 Capillarity
- 12 Atmospheric Pressure and Barometer

4. Report made 1887.

13 Elasticity of Gases

14 Air Pumps

15 Water Pumps, siphon

Heat

1 Expansion of Liquids and Gases

2 Unequal expansion of solids

3 Thermometer

4 Conduction

5 Temp. of Mixture of H_2O

6 Specific Heat of a solid

7 Latent heat of ice, steam, vapors

8 Heat from friction

Magnetism and Electricity

1 Properties of temporary and permanent magnets

2 Magnetic Curves

3 Simple galvanic cell

4 Useful forms of galvanic cells

5 Effect of current on needle

6 Electro magnetism

7 Influence of resistance on conduction

8 Chemical effects of current

9 Heating effects of current

10 Induction

11 Telegraph and Telephone

12 Frictional electricity

13 Electrical Machine

14 Leyden Jars

Sound

1 Vibration and production of waves

2 Resonance

3 Interference (Fork and Jar)

4 Sonometer

Light

1 Photometer

2 Reflection,- plane and curved mirrors

3 Refraction

4 Dispersion and Spectra

5 Total reflection

6 Lenses - construction of images

7 Combination of Colors.

While the above definition of physics held good for some years, yet there was rapid development. As men learned more about the subject and its value, changes soon followed. Again it was the NATIONAL EDUCATIONAL ASSOCIATION which in 1892 appointed a committee known as the Committee of Ten, which should standardize the physics course.⁵ Probably nothing better can be done than to give at least a few of the ideas embodied in the resolutions submitted and adopted. The report was unanimous, and was considered fair by practically all. Some of the more important

5. Com. of Ten, 1892.

resolutions follow:

- 1 The physics course should be in the fourth year.
- 2 At least two hundred hours should be devoted to physics in the high school.
- 3 There should be no distinction between courses for those who were going to college and those who were not.
- 4 The course should consist of laboratory and text combined. At least one half of the time devoted to the subject should be given to laboratory work, which should be largely quantitative.
- 5 Students should not be expected to rediscover scientific laws.

We have in the above resolutions clear statements on very vital points. The first one was argued for some time in the committee rather heatedly, some wanting physics the third year. It was argued that algebra and geometry should precede, although some contended that little of the mathematics indicated was necessary. The question of two courses in physics in the High School has not been definitely decided yet. There seemed to be an over emphasis on the amount of time to devote to laboratory work. The quantitative work was probably emphasized because of Harvard's influence.

The list of experiments suggested by the Committee of Ten included six in general properties of matter, twenty in mechanics of solid and liquids, seven in heat, eleven in sound and light, and nine in electricity and magnetism. These experiments were included in practically every High School course and were considered

favorably because of their quantitative character.

The Committee's report included fifty-eight experiments while that of the College Entrance Examination Board contains but fifty-one. The latter was adopted in April 1909.⁶ The following experiments appearing in the former do not appear in the latter.

Mechanics:

1- From known weight of a given length of wire, find the length of a roll of fine wire from its weight.

2- Find capacity of a bottle by weighing with water, Hg. and empty.

3- Experiment on elasticity.

4- Pressure of liquids, as to depth and direction.

5- Siphon.

6- Find weight of a column of mercury in a tube per centimeter by measuring the length and weighing the mercury.

7- Calculate pressure of atmosphere by weight of a column of mercury.

8- The law of distances of points of application of two parallel forces from the points of application of their resultant or equilibrant.

9- Comparison of masses by inertia.

Heat

1- Capacity of calorimeter

2- Latent heat of steam.

6. Ninth Annual Report of the College Examination Board 1909.

Sound

- 1- Relation of pitch to length in wires.
- 2- " " " " tension " "

Light

- 1- Relation of angle of incidence to angle of Refraction
- 2- Critical angle of Water.
- 3- " " " Kerosene.
- 4- Size and position of the virtual image in a converging lense.

Electricity

- 1- Constancy of the two fluids Daniell cell, and change of weight of the elements of the cell.
- 2- Electro-motive force of metals.

The experiments numbered 1, 2, 3, 6, 8, and 9 Mechanics are certainly far from being practical. Both under heat, 2, 3 and 4 under light, and 2 under electricity are of little practical value. The Committee of Ten gave some valuable suggestions regarding the physics course in its day. But after eighteen years conditions are different, and much included in the original course is now considered unessential and unimportant. Ten years' growth (1895-1905) shows some influence of the report of the Committee of Ten. In most cases the course extended over the entire year. Laboratory work received much attention. However the recommendation concerning the year in which it was deemed best to give the course was not taken very seriously. While the committee believed it should be given the fourth year, the schools were divided even-

ly (1894) between the second and third years.⁷

While the tendency, in the main, is towards practical physics, yet there is a slight tendency to popularize the subject. This is shown by seven recent texts which contain discussions and descriptions of electricity and electrical appliances amounting to 27% of the whole.⁸ In a conference on physics for secondary schools, this undue attention to electricity was severely condemned.⁹ Physics teachers were cautioned lest the subject be made too utilitarian. We should bear in mind that practicality is inherent in the student and not in his knowledge.

In this connection it may be mentioned that attempts have been made at different times to eliminate the 'absolute' units from the secondary physics course.¹⁰ As was previously mentioned, it has been proposed that the terms erg and dyne be omitted. The same idea was considered at Des Moines recently, and while no vote was taken, the sentiment seemed to be opposed to such action. At the same meeting it was agreed to retain "Kinetics" in the course.

In May 1907, the College Entrance Examination Board appointed a commission to consider the revision of the physics requirement. This commission consisted of ten members chosen from the leading scientific associations of the Central States and of New England. The commission made both majority and minority reports in November 1908. They were unable, however, to recommend a revised statement of the requirement in physics.

7. Dexter, E.G. Sch. Rev. 14: 262.

8. Table I Section III Chapter I, Page

9. National Educational Association Report 1901.

10. Sch. Sci. and Math. 1909. Vol. 9.

At this juncture, a committee of secondary school men was appointed. (With the consent of the commission). To this committee were referred the reports of the commission for full and careful consideration. At the April meeting of the College Entrance Examination Board in 1909, a unanimous report was made upon a revised definition of the physics requirement. The definition was adopted at once and takes effect in 1910. The membership of the committee was selected from the following schools: Roxburg Latin School, Yateman High School, Phillips Exeter, William Penn Charter School, Englewood High School, and Boy's High School (Brooklyn).¹¹

This unit in physics has some definite regulations. The time limit of at least one hundred and twenty hours of sixty minutes each is good; time in laboratory^{is} one half face value. Sufficient time is taken to really get an adequate idea of the subject. The knowledge of physical laws is a matter of growth and development. Then, too, sufficient time is allowed for review. This has been a serious handicap in all science work and especially so in physics. Time has been limited and the course^{is} so extensive as to admit of little repetition. Surely truer concepts will follow the new adoption.

The definition provides that instruction in physics shall include the study of one standard text book, lecture, table demonstrations and individual laboratory work. The text book is to be used more as a guide and as a means for getting a connected and comprehensive view of the subject, than to be studied as a text

11. Ninth Annual Report of the Secretary of the College Entrance Examination Board 1909.

for the science itself. Care should be exercised in the use made of lecture table demonstrations. Too often the lecture is a means of entertainment rather than instruction. It should be used chiefly as a means of illustrating physical facts and phenomena in their qualitative aspects and in practical applications. The time required for experimental work in the laboratory is at least thirty double periods. The required number of experiments being thirty, it is necessary that one be done each double period on the average. The list of suggested experiments provides for a wide range of observations. Laboratory work is needed chiefly to supplement the student's own fund of knowledge. He is trained in observation also. The exercises should be general and not too difficult, and most of all free from unintelligible units. It seems that "per cent of error" may as well be discarded, because little good can come from the calculations. In this connection we are cautioned against too great precision if it leads to the use of complicated apparatus in which the principle involved would be obscured.

One very noticeable feature of the new unit in physics is the omission of absolute quantities and the larger physical theories. Absolute units were recently introduced for the purpose of greater precision and accuracy. This however was for those who were preparing for college. Such theories as that of gases, of electrons and ions, and the electro-magnetic theory of light are omitted. These together with the absolute units have rightfully been left for the College. No one disputes the fact that any at-

tempt to thrust such difficult matter upon the mind of the average High School student, ends in discouragement. It is estimated that only one out of every 125, 000 students of physics becomes a specialist. This one must know every theory and unit, but it would be clearly wrong to require all this knowledge of the many who do not become eminent in the scientific world.

One thing further: when we compare practical knowledge with theoretical, there is a decided tendency to choose the practical. We can make use of the practical in our daily experiences and hence need it the more. Many experiments and many subjects are, in themselves, interesting, but do not possess practical value. For instance, of what practical value to a boy is the fact that the acceleration due to gravity is 979.45 in his home town? Or again: where does the average boy have use for the information that the latent heat of steam is about 537 which he is asked to find by experiment? Or how does he use the fact that the number of vibrations of a pendulum varies inversely with the square root of the length.

The new definition is certainly a step forward. That physics is becoming more practical and educational is clearly evident. The student is now to get something real and vital. He is to be spared many nonessentials and if the course is followed closely, he will be developed rather than taught. The course is arranged more as an effort to help the student to interpret his physical surroundings than to prepare him for college. A very creditable feature of the whole thing is that the unit was not wholly defined

by college men. The final work was done by a committee of secondary school men. Thus the definition is the result of the cooperation of college and high school. There are some, however, who object to this, saying that the matter should rest wholly with the colleges. The new definition seems to be based upon the Harvard experiment list and embraces much the same subjects. After all, whether a unit is good or bad depends much upon the teacher. The new unit gives the teacher much freedom. The course can be so adapted as to meet the requirements of any community. Physics is not made easy. While students may be better able to pass the examinations now, there will be failures. Failures would result under any system.

In summing up the actions of the scientific bodies and associations which have influenced the course in physics, we see that there is a general feeling that improvement is demanded. The greatest problem doubtless is that of the content of such a course. In all probability, there will be many changes, but in the main the plan is definite. There has been so much talk about the non-practical that unless we are very careful we may go to the other extreme.

As an authority on such matters believes, "The practical is to be used as the basis for consideration of theoretical problems. Unless the study of the practical leads to larger principles it takes a great deal from the study of physics. Physics can be made educational only when the teacher goes on to the general conclusion and does not stop with the practical application. To use the practical as an illustration of the general principle is reversing the order. The theoretical problems in physics developed historically from practi-

cal necessities of the commercial world."¹²

In our brief survey of what has been done by organizations of science teachers, let us bear in mind the fact that the new unit is a matter of growth and development. There have been leaders in the movement, but the teacher who never gets in ^{to} print has had something to do with it. He has sent students to college who either do well or ill- thus reflecting his own teaching to a certain extent. The new plan gives him greater freedom in planning his course, thus allowing its adaptation to every condition. Dr. Mann presented a paper at the meeting of the Department of Superintendence of the NATIONAL EDUCATIONAL ASSOCIATION in Chicago February 1909 in which he quoted principles prepared by Dr. J.L. Meriam for guidance in the selection and arrangement of the content of a physics course.¹³

Those principles are:

1- That content has a place in the physics course which meets real, present needs of the pupils.

2- Only that content has a rightful place, in the study of which the pupil has a conscious motive.

3- Only that content may be admitted which the pupil can comprehend and the significance of which he can appreciate.

4- Only that content may be admitted which contributes to the continuity in the development of the special problems being studied.

12. Mann C.R. Personal note to writer, Apr. 26, 1910.

13. C.R. Mann: Educational Review, 38: 159.

SECTION III.

EXECUTION

Much time and care were spent in the formation of the physics course and in defining the unit in physics. When these ideas were once determined upon, however, the next step was to arrange the subject matter in accordance with the standard unit. As a result, many text books were written. There is a great variety of these texts, beginning with Steele's "Fourteen Weeks in Physics" 1879, and Gage's "Elements of Physics" 1885, down to Adams 1908 and Linebarger 1909. Some very early texts are Comstock's "Natural Philosophy", Well's "Natural Philosophy" and Ralfe and Gillett's **Hand** book of Natural Philosophy. The last mentioned one was designated for use in the Harvard entrance examinations in 1876. All the above texts must have been in use before that year. Arnot's "Elements of Physics" 1877 was recommended by Harvard in 1881.¹ These texts represent in the concrete, the principles of the physics unit as interpreted by the different authors. By comparing the texts it is easy to see how the authors regard the relative value of different divisions of the subject.

The function of a physics text twenty years ago was to give information. The facts were published together much as those in a dictionary. Statements contained in the books, while doubtless true today, left no opportunity for the student to make judgments. An example, Arnot's Elements of Physics (1887) contained 837 pages² without an index but with a table of contents covering thirteen

1. Harvard Catalogue 1881.
2. Mann, C.R. Sci. 30: 789.

pages. It covered a vast field, but it did not contain a single problem nor was there a single question put to the reader. Apparently the author intended that his readers should have no thinking to do in matters relating to physics, for he tried to anticipate all questions and controversies.

Arnott's text, of course, was the extreme of its type, but it shows the tendency of that time. No provision was made for the individuality of the student. These old books mentioned above had their influence on men now well along in life, although they have long since been retired from use, because of their superficial and unsatisfactory character. This changed attitude is due to the fact that our estimate of the boy is different now. We now look upon him as a growing thing to be developed, trained and fed, rather than a mere vessel to be filled with learning.

Let us make a comparison of some text books, showing the relative number of pages, articles and problems, from Gage 1882 to Crew and Jones 1909. A brief comparison of Ralfe and Gillett's text in physics with, for instance, Adams 1908, shows Ralfe and Gillett 230 pages, 351 paragraphs; Adams 478 pages, 560 paragraphs. Thus we see an increase of over 100% in the number of pages and over 50% in the number of paragraphs. Since each paragraph must stand for a particular idea, there are 50% more ideas or information required of the present high school student than formerly. Of course, the increased amount of matter comes partly from fuller explanations of old topics. While new ideas have been added, the old ones were retained.

It is clear that the subject-matter has increased exceedingly.

This increase, however, has been in the addition of new topics rather than in the change of old for the new. The old texts contained the same general divisions practically, as do the new ones. That is, we find the main divisions - Mechanics, Sound, Heat, Light and Electricity and Magnetism, in both the old and the new texts. It is to be kept in mind then, that the science of physics of 1876 contained all the elements that we now consider necessary. Let us now consider the comparisons made in Table I.

TABLE I.

	<i>Year Published.</i>	<i>No. of Pages</i>	<i>No. of Articles</i>	<i>No. of Illustrations</i>	<i>No. of Problems</i>	<i>No. of Chapters</i>	<i>Topics under C (Index)</i>
Gage (El.)	1885	439	367	303	348	66	28
Hall-Bergen	1897	586	446		492	34	
Wentworth-Hill	1898	440	426	357	644	88	58
Hoadley	1900	453	522	497	374	10	70
Gage (Prin.)	1902	359	323		480	8	
Carhart-Chute	1902	432	522	322	455	7	53
*Higgins	1903	403	392	253	159	8	38
Andrews-Howland	1903	386	615	242	377	9	58
Coleman	1906	439	530	340	197	12	35
Mann-Twiss	1906	453	416	235	216	33	60
Millikan-Gale	1906	438	614	494	527	22	37
Gage (Prin. Rev.)	1907	547	562	414	534	9	37
Carhart-Chute	1907	427	525	322	408	7	53
Mumper	1907	411	305	429	385	17	60
Hoadley	1908	463	582	494	220	11	76
Adams	1908	490	560	348	434	7	72
Crew-Jones	1909	435	331	357	687	10	37

Column headed "C" gives the number of topics given under C in the index.

*Higgins is offered to two year high schools only.

No. Problems	Mechanics No. Problems	Sound	No. Problems Light.	No. Problems Heat	No. Problems Elec-Mag.	No. Pages Mechanics	No. Pages Sound.	No. Pages Heat	No. Pages Light	No. Pages Elec-Mag.
206	23	34	42	45	138	52	41	74	93	
225	20	104	81	62	250	28	102	89	77	
410	16	28	92	98	211	24	42	52	89	
168	29	45	52	80	141	27	38	60	105	
322	14	38	55	51	128	31	44	57	84	
226	57	43	39	20	159	50	48	64	113	
105	15	6	17	16	118	37	49	50	78	
165	34	70	55	53	124	29	37	41	30	
68	22	30	57	20	156	41	52	57	110	
83	46	25	51	31	125	68	54	77	110	
159	37	85	140	106	128	45	100	94	115	
222	12	70	30	55	152	47	61	105	180	
220	47	34	67	20	127	45	42	57	111	
178	26	31	76	74	163	28	68	44	99	
130	19	13	31	37	138	43	44	58	102	
211	36	31	39	67	162	51	79	57	134	
336	35	71	132	113	164	30	48	57	97	

3. The data in Table I was secured from the texts themselves.

Table I presents an analysis of seventeen texts on physics from Gage's Elements 1885 to Crew and Jones 1909. By referring to column III we notice that the variation in the number of pages is considerable. Note the three texts of Gage alone: the 1885 edition with 439 pages; the 1902 edition with 359; and the 1907 edition with 547 pages. The edition of 1907 contains 547 pages with 562 articles. The great increase in subject-matter is due to the great amount of research work that was going on, and to the demands of the times to be up-to-date. The teachers who selected text books insisted that all the latest advances in science be in the modern texts. Consequently there was a great increase in the size of the books. A comparison of Hoadley 1900 with the revision of 1908 shows an increase of ten pages and sixty articles. Crew and Jones 1909 shows a slight decrease both in the number of pages and in the articles. There is no doubt that the average text contains too much material. Take Millikan and Gale, for example, with its 448 pages and 614 articles. Counting the physics course one hundred and eighty hours there could be less than twelve minutes to each article. This includes time given to laboratory work, recitations, problems and discussions. Since each article means a new idea it is clear that many articles will not be well understood.

In order that a clear understanding of the great amount of material in the physics course and the consequently short time for each new article or idea may be had, a brief comparison is made:

Text	Year	No.pp.	No. Art.	Time to each Art.	pp. per day
Gage (El.)	1885	439	367	14 min. 40 sec.	2.5
Wentworth-					
Hill	1898	440	426	16 " 45 "	2.5
Hoadley	1900	458	522	13 " 46 "	3.
Gage (Prin.)	1902	547	562	12 " 48 "	3.
Higgins	1903	403	382	18 " 43 "	2.2
Millikan-Gale	1906	463	614	11 " 43.6 "	2.6
Hoadley	1908	463	582	12 " 25 "	2.5
Crew-Jones	1909	435	331	32 " 30 "	2.4

With the exception of Higgins (which is used in two-year high schools only) the number of articles has gradually increased from Gage's Elements (1885) to Millikan and Gale (1906). Consequently the period of time to devote to each article grows smaller. Since each article stands for a separate and distinct idea, it is evident that the course is being crowded more and more. The capacities of students have not increased correspondingly. Therefore, it is very evident that we are trying to grasp too much material in a short time.

There seems to be a change since Millikan and Gale (1906) in the number of topics. Whether the criticism regarding the crowding of the course was responsible or not, the 1908 edition of Hoadley, and of Crews and Jones 1909 have reduced the number of articles very materially. By comparing Crew and Jones with Millikan and Gale we see that the former text allows thirty-two minutes to each topic, while the latter gives less than twelve. Not only must the student

get the topic in the allotted time, but also the laboratory, lectures, problems, discussions and all the work connected with it. We do not wonder that many fail to grasp the work. The wonder, perhaps is, not that seventy per cent fail in the College Entrance Examinations, but that thirty per cent ever pass.

Compare two texts, Millikan and Gale, and Mann and Twiss issued the same year (1906). These are different types of texts. Millikan and Gale is more formal and includes very difficult matter. It is clearly written to prepare for college and consequently gives much material that is valueless for ordinary purposes. Mann and Twiss, on the other hand, is written to help the student in the solution of present problems and is very practical. The problems are real and vital. Millikan and Gale has thirty-five more pages and fifty-two more articles than Mann and Twiss. The former has twice as many illustrations and problems as the latter.

By referring to columns 15, 16, 17, 18, and 19 we shall see how the emphasis on material has increased or decreased, since 1885 for each division of physics. Mechanics shows an increase; Sound has changed but little, decreasing a little if anything; Heat has changed little; Light has perceptibly decreased; and Electricity has increased.

That the number of pages should vary is due to the fact that some departments of physics were being investigated. When a teacher selects a text he insists that it include all new matter. Thus we see how the secondary teacher influences the subject-matter in the text.

I then shows, in the main, that there has been a decided increase in the number of topics considered necessary for the high school course. Although colleges disclaim any responsibility for this congested condition, secondary school men feel under constraint.⁴ When colleges issue descriptive lists of laboratory experiments and formulate required courses basing the entrance examination on such lists and courses, no one can deny that the secondary school course will be regulated very much in accordance with such requirements. The most notable lists are the descriptive lists issued by Harvard, The National Educational Association, and the College Entrance Examination Board.

A second comparison of texts as to subject matter:

Index Comparison:

Under "C" in Gage (1885) twenty-eight topics.

" "C" " Mumper (1907) sixty topics. There are twenty-four topics in common, and thirty-two topics in Mumper are not found in Gage. Five topics in Gage are not in Mumper. They are;

1. Cutting glass - (practical).
2. Celestial Chemistry and Physics.
3. Compound Substances.
4. Constitution of Matter.
5. Correlation of energy.

More important topics in Mumper
not found in Gage:

Caisson

Centigrade scale

Less important topics:

Calorie - colorimetry

Cathode

Charles' Law

Circuit, Electric	Chromatic aberration
Compass.	Coefficient of expansion
Compound Microscope	of gas
Concave Lenses and Mirrors	Coherer
Conduction	Conjugate foci
Cooling by evaporation	Coulomb
Commutator	Critical temperature
	Cowke's Tubes
	Curvature Centre of -

The above comparison will show that the subject matter has increased decidedly.

One thing that is, to some extent at least, responsible for the congested condition of high school physics, is the fact that such wonderful progress has been made since 1876. Scientific research has been, and is at fever heat. Universities demanded original research of their scientific men as a basis for promotion. These men therefore added much to the scientific learning. When they went out from colleges into the secondary schools they carried with them all this added and highly specialized training. The abilities and needs of the pupils were lost sight of in this great swirl of investigation and scientific activity.

A second point: The development was fastered by text book writers, publishers and makers of apparatus. Publishers refused to print books unless they embraced all recent discoveries. Why? Because too often teachers, in selecting texts, would be influenced by the recent developments and new phases. We insisted upon a book's

being up-to-date. Books without a few articles on X-rays, wireless, electrons, ions and aeroplanes were rejected.

COMPARISON OF TEXTS

TABLE II.

Texts	I The Lever No.pp.	II Latent Heat No.pp.	III Illustration
Steele	2 5/4	1/2	9
Gage El.	2	1	4
" Intro.	1/2	4	1
" Prin.	1/4	5 3/4	2
Hoadley	4	2	5
Carhart and			
Chute	2 1/4	2	5
Higgins	2	1	6
Andrews and			
Howland	2 1/3	2 1/2	7
Coleman	4	2	8
Millikan and			
Gale	4	2 1/2	12
Mann and			
Twiss	2 1/2	1 2/3	3
Adams	2 1/4	2 1/4	9
Crew-Jones	2 1/4	1	9

The foregoing table shows the number of pages given to the important subject the lever and the less important latent heat.

A third comparison of texts (Table II) shows the relative emphasis placed on the important topic of the lever and on a less important one, latent heat, by different text books. Steele gave $2 \frac{3}{4}$ pages to the lever while $1 \frac{1}{2}$ was given to latent heat. Gage seemed to emphasize the lever less and latent heat more in his successive editions. Andrews and Howland gave more space to latent heat than to the lever. The knowledge of the lever is of vastly greater use than the knowledge of latent heat and should receive much more attention. When we consider the relative value of latent heat and the lever, we certainly see that the lever receives much less emphasis than it deserves.

To summarize Chapter I briefly: There is every evidence that the course in physics in secondary schools is becoming more satisfactory to all concerned: To the college first of all, because the students entering come better prepared. They have not merely memorized the physics text as was formerly the case but are trained and developed for scientific work.

According to Thos. S. Fiske's report as Secretary of the College Entrance Examination Board for 1909, six hundred and nineteen candidates took the examination in physics.⁵ Of this number

4.7%					
18.9%	"	"	75%	"	90%
31.3%	"	"	60%	"	75%
14.9%	"	"	50%	"	60%.

Physics was one of the four subjects in which a grade of 100%

5. Ninth Annual Report of College Entrance Examination Board, (1909).

was obtained. The above figures show that a very high per cent (69.8%) of the students were above 50%, while only 30 2/10 % were below 50%. Thus the secondary students are reasonably well prepared for the entrance examinations. They may not cover so much ground as formerly but they are acquiring the scientific habit and power which the colleges so desire. Then the course is more satisfactory to the secondary physics teacher. It is definite and yet grants the teacher much freedom. He feels too that he is not following the directions of some one else solely, but that the plan partly is of his own making. The college has acted fairly toward the secondary schools and both are in closer harmony than ever before perhaps.

Last, but not least, the student himself is being considered. He is being trained to observe and explain his environment. He is surrounded by the physical world on every side; why should he not be equipped to interpret? The emphasis has changed from the course to the one pursuing it. The student is the greatest gainer perhaps of any one affected by the physics situation. It is well for all that each understands the other better and ^{is} willing to grant concessions. The course in physics is now being given more to supplement the student's own experiences and to assist in organizing fact already known to him, than as a preparation for a college course. The framers of the course had in mind the average student who, in all probability, will never go to college. Possibly the physics course that prepares a student best to remain at home prepares him best for college.

Are physics teachers presenting material that properly belongs in a course for high school students? Are the texts which are intended to conform to the generally adopted physics unit meeting the real needs of the student? To be more specific: are we really getting practical working knowledge out of our average course? Some tests were made in the course of this investigation to determine what character work was of greatest interest to the student, and why? What, in a certain exercise, gives it greater worth than is found in another just as easy and simple? The material will be presented in the form of a list of practical problems following pretty closely the adopted unit. The proposed problems are general and are selected from ordinary relations and under conditions familiar to many.

In the present paper, an attempt is made to offer something of a constructive nature to the physics situation. The suggestions made are based upon both tests in classes and general observations.

CHAPTER II.

STATEMENT OF PRACTICAL PROBLEMS.

The following list of problems covers the topics as outlined in the new physics definition. Some of the topics are not included in the problems, for it seemed best to omit a few, in-as-much as the principles involved in them are also involved in the problems given. Difficult problems are purposely omitted.

Statement of practical problems.

II Mechanics

A.- Solids:

1- Two boys are carrying a bucket of water weighing $22 \frac{1}{2}$ pounds, on a hoe handle, the length of which is, $4 \frac{1}{2}$ feet. If the bucket is suspended 2 feet from A, how much does he carry? How far from B would the bucket have to be suspended in order that he might carry twice as much as A?

2- In building a fence, wires are stretched from a corner post. The pull in one direction is 1500 pounds, and in the other 2750 pounds. What is the resultant pull on the post ?

3- At a street corner, a telephone pole supporting a lead cable, is held in position by two guy rods at right angles. If the force exerted on each rod is 1850 pounds, what is the resultant pull on the cable if it makes equal angles with the two rods?

4- Steam is seen to rise from the whistle of a locomotive whose distance away is one mile. If the temperature and wind are neglected how long will it be until the sound is heard? (The velo-

city of sound is 1090 feet per second).

5- A baseball weighing 9 oz. is struck by a bat weighing $3 \frac{3}{4}$ pounds moving at the rate of 30 feet per second. What is the velocity of the ball when it strikes the pitcher's mitt 60 feet away?

6- At a county fair a certain inclined plane was 110 feet long. If the distance passed over in one second was $7 \frac{1}{2}$ feet, how long would it take to slide down the plane? How far would one slide in the third second?

7- A man desires to raise a stone weighing 600 pounds. If his weight is 165 pounds, how far from the stone must a block be placed in order that it may be raised with a lever 12 feet long?

8- Two men are digging a well, and are using the wheel and axle to raise the dirt. What power must be exerted on the wheel of $2 \frac{1}{2}$ feet in diameter in order to raise a 750 pound load, the axle being 10 inches in diameter?

9- A farmer is drawing hay into his barn loft with a hay fork and system of pulleys. If the load on L is 1575 pounds, how much force must be exerted by a horse at P in raising the load?

10- A drayman is able to exert a force of no more than 250 pounds. A barrel weighs 425 pounds and the back of the wagon stands 3 feet and 3 inches high. Could he load the barrel by using a beam 10 feet long as an inclined plane? What is the shortest incline up which the barrel could just be rolled?

II Mechanics

Bl. Fluids:

1- A cylindrical vessel 18 inches high is filled with kerosene whose density is .83. Find the pressure on walls and bottom if its diameter is 12 inches?

2- If in the above problem a force of one hundred pounds be exerted on the surface of the fluid, calculate the increased pressure on each square inch of the bottom? Find the pressure on an area of one square inch whose average distance below the surface of the liquid is 5 inches.

3- In the water system of Columbia the pressure is about 80 pounds per square inch. How much pressure would have to be exerted upon the cross-section of a pipe whose diameter is $4 \frac{1}{2}$ inches in order that the pressure would reach 85 pounds per square inch inside a connecting pipe of $1 \frac{1}{2}$ inches in diameter?

4- Compare the pressure on the bottom of a cylindrical vessel whose altitude is $7 \frac{1}{2}$ inches and diameter $7 \frac{1}{2}$ inches when filled with water and when filled with sulphuric acid. (Specific gravity of the acid is 1.8).

5- The volume of the cylinder of a bicycle pump is 25 cubic

inches. How does the density of air vary as volume decreases to $1/2$, $1/3$, $1/5$, and $1/10$ of its initial volume?

6- At sea level the barometer stands at 76 cm. If the fall is 0.1 inches for every 90 feet ascent, find the reading in Glen Curtis' biplane at the height of 250 meters.

7- To what height does the lift pump operate effectively? Why no higher? What arrangement is made whereby water can be pumped to a height greater than the one above given? Upon what principle is such an arrangement based?

8- The density of the air at 0°C and 76 cm. pressure is .00129. If the density in the bowl of a vacuum cleaner has been reduced to $1/3$ its natural density, what is the pressure per square inch tending to crush the bowl?

III Heat.

1- (a) The temperature of melting paraffine is 104°C . What is this reading on the Fahrenheit scale?

(b) The melting point of pure iron is 2732 F. What is this reading on the Centigrade scale?

2- When heat is applied to a piece of iron expansion takes place. If the increase in length is .000366 Cm. per foot per degree, what would be the increase in volume of a cubic foot of iron in heating from 0° to 50°C ?

3- The coefficient of expansion of dry air is .003665. What volume would a gallon of air at 20°C . occupy at 75, if the pressure remains constant?

4- A quart bottle is filled with air and sealed at 20°C . Calcu-

late the increased pressure per square inch on inner surface of the bottle, if it is set in the sun and acquires a temperature of 35° Centigrade.

5- It is well known that some bodies heat much more readily than others. The ones easiest to heat are said to have the lowest specific heat. Compare the amounts of heat necessary to raise a pound of water and a pound of lead through a range of 50° C. (Specific heat of lead is .033).

IV Sound;

1- Sound originates in a vibrating body. How is the energy of vibration carried to the ear?

2- Pitch depends upon the number of vibrations. Of a string 50 cm. long vibrates 256 times per second, what will be the pitch of a string $1/5$ as long? (The number of vibrations varies inversely as the length).

3- The velocity of sound depends upon the temperature. The velocity at 0° C is 1090 feet and increases 60 cm. per degree increase of temperature. Find the velocity of sound on a summer's day when the Fahrenheit reading is 85° .

4- A party of travelers saw steam rising from a locomotive. In $2 \frac{3}{4}$ seconds the whistle was heard. What distance away was the locomotive, if the temperature was 24° C. and no breeze?

6- A gun ~~fired~~ fired. In $3 \frac{1}{2}$ seconds the echo returns from a distant wood. How far away is the wood if the temperature is 90 Fahr.?

V Light.

1- Two flames cast the same shadow on the screen. One is 25 centimeters and the other 65 centimeters from the object. Calculate their relative candle power.

2- If one can read well when at a distance of 2 meters from an incandescent light of 32 candle power, at what distance can he read equally well when an arc light of 500 candle power is used?

3- The angle of reflection is equal to the angle of incidence. Locate the position of the image of an object 12 inches in front of a plane mirror.

4- A spherical (concave) mirror has a radius of curvature equal to 18 inches. Make a drawing showing the character and size of the image of an object 100 cm. from the mirror.

5- An object 5 inches long is placed before a double convex lens 100 cm. away. Make drawing showing the image found and indicate size of image. ($F. = 20$ cm.).

6- Explain how the eye accommodates itself in focusing objects upon the retina at different distances.

7- The prism is capable of separating white light into its components. Make a drawing to show in what order the different colors are arranged.

8- Make a drawing to show how the rainbow is formed and why the colors have a certain arrangement in the primary bow, also a similar drawing of the secondary bow.

9- The magnifying power of a simple lens is $\frac{25}{f}$ (where f is the focal length). How many times is the size of an object magnified,

when placed at the principal focus if $f = 7/4$ inches.

VI Magnetism and Electricity.

- 1- Explain how a magnet is made. Upon what does the strength of a magnet depend?
- 2- Why does a magnetic needle point in a north-south direction (nearly)? Does the compass needle on a steamer always point in a direction parallel to its original position as the trip is made from New York to Liverpool?
- 3- State clearly how to determine the kind of electric charge on a given body A when only an electroscope, a glass tube, and a piece of silk are given.
- 4- What is the function of a condenser? How does it operate?
- 5- Show in what way the electric current breaks up water into its component parts.
- 6- Explain the phenomena connected with electrotyping.
- 7- Make drawings of the electric bell and telegraph systems.
- 8- Ohm's Law is $C = E/R$. What current will a given cell produce if its resistance is 2.5 ohms and the difference of potential between its terminals is 1.75 volts?
- 9- An electric door bell is out of order. Give all possible conditions which may be the cause.
- 10- An incandescent light fails to give light. What trouble may there be in that part of the system within the room?
- 11- I find my telephone out of working order. How shall I test it to find where the trouble lies? How can a line be tested to locate where it is grounded?

CHAPTER III.

GENERAL DISCUSSION

SECTION I.

Discussion of Problems:

Ideas, in general, are most firmly grasped when accompanied by concrete examples. There may be one illustration after another, but these are for one purpose only: that the idea may become more definite and capable of being used intelligently. Thus the concrete illustration is used only that a working knowledge of an abstract principle may be gained. When once the concept is clear, the illustration is no longer valuable.

Now the problem in physics is used somewhat as an illustration. It is of value to the extent that it helps to make a principle of physics clearer to the student. Oftentimes a physical concept can be more easily grasped if only illustrated by a simple problem. The character of problems should be a matter of some concern. Students should be guarded against receiving erroneous ideas through carelessly constructed problems. Certainly no thinking person will insist upon giving problems indiscriminately. Conditions must be studied; the abilities of the students should be taken into consideration. Problems should not be so difficult that the physics is lost in the mathematics. Since we expect to discard the problems as soon as ideas are made clear, there is no reason for any but the simplest.

Besides being simple in statement and involving only the most

fundamental algebraic or geometric processes, problems should be extremely practical. That is: ordinary everyday conditions only should be included. The student will undoubtedly see the meaning of problems if they involve something with which he is familiar. Problems can never be truly concrete until they relate to the student's own experiences. For instance, if it is proposed to teach the relation of the Metric system to the English system definite necessary measurements should be made. These measurements may be the dimensions of a room in one system to determine the floor space, the wall space and the ceiling in the other. Give the student something concrete - something that involves what he actually knows. For instance: ask him how much paper is required to make a book of certain dimensions, giving the results in square units of both the English and Metric systems.

We must be careful to make problems really concrete. Let the student make problems involving measurements made by himself, or from experiences vital to him. There are few students who do not know how milk is measured or how coal oil and gasoline are sold. Problems of this character would help to acquire a knowledge of the units of volume in different systems. A simple problem proposed by a student who has actually worked out the conditions is of vastly more importance than one in which the conditions are foreign to him.

In mechanics of fluids we can easily find practical problems. There is the reservoir or standpipe with the water at a certain depth to find the lateral pressure per square foot. In cities where there is a water system valuable problems involving the dis-

tribution of the pressure as regulated by pumps may be given. Everyone has seen the steam gauge; from its reading the pressure can be calculated on the pipe sides and inner surface of the boiler.

The problem of the variation in the pressure on the bottom of a vessel when filled with different liquids is valuable. The conception of density can be easily implanted in the mind of the students with this type of problems. After liquid pressure is well in hand gaseous pressure may be taken up. It is well known that a bicycle or automobile tire is harder to indent as air is pumped into them. The density of the compressed air increases, and the relation between volume, density and pressure may be worked out.

It is very probable that the subject of mechanics of solids appeals more to students than mechanics of liquids. We have many machines involving the principles of the lever, the wheel and axle, and the inclined plane. The principle of work has already been made use of in the student's earlier experiences. He will be interested to learn how to calculate the advantage he can gain by the use of the different forms of machines. It will be of great interest to learn just how a state of equilibrium of a see-saw may be brought about by two boys of unequal weight at different distances from the point of support. Every student has seen the pulley in use by painters, sign hangers, or house movers. There will be the keenest interest to learn just how much power is gained by using different numbers of cords. There are so many varied applications of the principles of mechanics of solids that little trouble will be experienced in formulating interesting, and at the

same time, suggestive problems for solution.

Some of the fundamental ideas of heat phenomena may be easily grasped by introducing the problem feature. By comparing the readings of different thermometers and making reductions from one scale to the other, the student may get a real working knowledge of the meaning of temperature. The problems of conveyance of heat claim the undivided attention, and lead easily to the very important problems of expansion. The property of expansion gives rise to various interesting problems. The pendulum for instance is of great value. Its change of length and the method of compensation are well understood. The blacksmith must have good judgment about the amount of expansion of metals when heated. Experience tells us that when wires on a fence contract, the corner posts are apt to be pulled aside. Another very interesting consideration in connection with heat is the relative amounts of heat necessary to raise the temperature of different bodies of approximately the same size through the same number of degrees. It is well known that iron heats more quickly than a vessel of water. A comparison of these different amounts gives us what is called specific heat. In all of its relations heat probably is of greater importance than any other division of physics.

In the case of sound, practical problems are less numerous than in heat. It is the experience of all that the tighter a string is stretched, the higher will be the pitch. So a list of problems on this point gives great stimulus. The problem of velocity perhaps is of the greatest importance since it can be so easily esti-

mated. It is well known that the farther away one is from the source of sound, the less distinct is the sound, or the longer it takes to travel a certain distance. A phase of sound often observed is that known as echoes. It has to do with the question of velocity. When an object is dropped into a deep well there are two interesting physical problems brought to our attention; the one is that of velocity of sound, and the other that of falling bodies.

When we come to the study of light, numerical problems are less easy to formulate, perhaps, than any list preceding. Of course, we can state problems involving photometry and by measuring distances and comparing intensities of shadows prove the law of inverse squares. Then there are the laws of reflection and refraction. Problems involving refraction through lenses are of great practical value, and help to fix correct ideas and conceptions relating to these wonderful phenomena of light in the mind. The important applications of the laws of reflection and refraction are made in the camera, the microscope, the telescope and in the adjustment of glasses to the human eye.

One other group of light phenomena may be mentioned; -those relating to the spectrum. Perhaps this group cannot be made very clear by the use of problems. The numbers involved are so large that one can hardly appreciate their significance. And yet, without the mathematical consideration, little meaning could be attached to the problems of color.

One further group of problems remains; those relating to electricity and magnetism. We have many things yet to learn in this field;

discoveries are being made frequently. For the student taking an elementary physics course, there are few problems that really help much.

$$\text{Ohm's law - } C(\text{Current}) = \frac{E.(\text{Electro-motive force})}{R.(\text{Resistance})}$$

or

$$\text{Amperes} = \frac{\text{volts}}{\text{Ohms}} \quad \text{-- may be used to advantage}$$

early in the study of electricity. This equation is based upon our conception of the unit of current strength, difference of potential, and resistance of a conductor. In practice the student may easily determine the current strength and difference of potential by direct reading. In the laboratory simple resistance boxes may be used.

Certain equations are given in elementary texts in which, if the quantities be properly substituted, the amperage may be found when cells or batteries are connected up in series or in parallel. Such problems help to make the concept of current strength clear to the student.

CHAPTER III.

SECTION II.

Observational Work.

After some year's experience in the teaching of physics, the writer is led to believe that science work has elements of interest not possessed by many other groups of subjects which have a place in the High School curriculum. During the past year (1909) in the University High School, the percentage of failure of students of scientific subjects is very much smaller than that in the case of other subjects. Without doubt the sciences are, as a whole, of greater interest than other groups of subjects because they possess a deeper and more vital human interest. Scientific work employs both hand and mind and therefore makes use of practically all faculties

While physics as a whole is of great interest, involving as it does principles so vital and so fundamental to us, yet there seem to be certain phases of it that appeal very readily to the student while there are others of which the opposite may be said.

It was to ascertain just what the particularly interesting features in physics are, and to inquire whether they may not be the basis for more successful work, that a few tests and special observations were made. The first test consisted in giving answers to a few questions. The class did not know that any kind of a test was to be made. The following are the questions:

- 1- What experiments are most interesting? Name ten in order of preference.

- 2- What in the experiment makes you enjoy it? - answer each in order.
- 3- With what experience did you associate each experiment, if any?
- 4- If no application was made at the time, what can you now suggest?
- 5- What other laboratory course have you taken?
- 6- Compare your previous laboratory courses with physics.
- 7- Arrange all high school subjects studied in order of preference

In answering the questions, only one was placed on the blackboard at a time. This prevented later questions from influencing the answers in any way. Before the first question was asked, the students were requested to look up all experiments which had been done up to that time. This was done in order that the students might recall everything and omit nothing from the present consideration. By either referring to the text or from memory the answers to question 1 was made.

Table III is a condensed form of the answers to question 1. Column A shows the number of times each experiment was mentioned among the ten of greatest interest, while column B indicates the number of times the experiments were put in first place. The work up to the time of the test had covered mechanics, sound, and heat. The number of students answering the questions was thirty-two, among which number were four girls. The thirty-two were fourth year students.

TABLE III.

Name of Experiment	A	B
1. Coefficient of Linear Expansion (Solids)	25	7
2. Siphon and Suction pump	20	3
3. Density of Solids and Liquids	18	0
4. Boiling (water)	17	3
5. Melting and Freezing	16	1
6. Pulleys	16	1
7. Heat of Vaporization of Water	15	1
8. Specific Heat	15	3
9. Equilibrium of Concurrent Forces	13	0
10. Heat of Fusion and Solution	12	1
11. Center of Gravity and Moments	11	0
12. Cooling by Evaporation	11	0
13. Buoyancy of Liquids	10	0
14. Conduction and Convection	88	5
15. Simple Pendulum	8	0
16. Steam Engine	6	0
17. Surface Tension	5	0
18. Transmission of Sound	5	0
19. Law of Lengths	4	3
20. Boyle's Law	4	0
21. Beats (tuning forks)	4	1
22. Falling Bodies	4	1
23. Wave Length (Sound)	4	1
24. Inclined Plane	3	0

Column A represents the number of times the experiments were mentioned. Column B, the number of times they appeared first.

The table shows that the experiment on the "Coefficient of expansion of solids" received the largest number of votes, and was placed at the head of the list by seven. According to the standing of the votes, then, this experiment was unquestionably of greatest interest. The answers to the second question give reasons for its great interest. Thirty-two different experiments in all were mentioned, eight being mentioned but once. Among the twenty-four given in the table, the inclined plane occupies the lowest place in point of number of times mentioned. It is not put in first place at all. The eight receiving a single vote are: the law of cooling, hydraulic press, relation of the centimeter to the inch, ~~the~~ velocity of sound, cohesion and adhesion, liquid pressure, the siren, and the cubical solids. One student put the last named experiment as his first choice, while another gave the relation of the centimeter to the inch first place. Only fourteen out of the thirty-two experiments received first mention; eight of these received but one vote each, four received three each, one five, and one seven. Eighteen experiments out of the thirty-two failed to be accorded first place by a single student.

In order to test the students further, an unexpected list of questions was presented much later. Since the coefficient of expansion ^(a), the siphon ^(b), the density of solids ^(c), and boiling ^(d) occupy places at the head of the list, the second test was given to see how well the students really understood the meaning of those four ideas. The result was as follows:

	Correct	Incorrect
(a)	25	7
(b)	21	11
(c)	22	10
(d)	26	8

At the same time four practical questions and four less practical ones were asked. In general the first group were answered.

The results of this test seem to warrant the statement that the practical is of greatest value, and that, therefore, our course in physics should be arranged with that in mind.

TABLE IV.

Why Experiments were Interesting.	Experiments given with reason for Interest.	No. Times given.	Total Times (incl. repetition).
I. Answers questions previously raised.	Falling Bodies	1	1
II. Novelty	Beats	1	10
	Specific Heat	3	
	Boiling	1	
	Siphon	4	
	Pressure of Gases	1	
III. Relates to Favorite Subjects.	Law of Lengths (music)	3	3
IV. Practical.	Pulleys	1	12
	Coefficient of Expansion.	6	
	Conduction and Convection	1	
	Pumps	3	
	One Centimeter - 2 Inch.	1	
V. New Information.	Wavelength by Resonance	1	10
	Cohesion and Adhesion	1	
	Conduction and Convection	5	
	Specific Gravity of Liquids	1	
	Specific Heat	1	
	Coefficient of Expansion	1	
VI. Explains Interesting Things.	Specific Heat	1	3
	Melting and Freezing	1	
	Coefficient of Expansion	1	
VII. Interesting form of Apparatus.	Heat of Fusion	1	2
	Specific Gravity	1	
VIII. Just Interesting.	Heat of Vaporization of Water	1	5
	Pumps	1	
	Coefficient of Expansion	1	

Table IV contains in brief outline the answers given to question 2. The different reasons were classified and placed in eight groups. The first column indicates the different reasons under which the answers fall. In some instances certain experiments were interesting for various reasons. For example, Specific heat was interesting because of novelty, because it afforded new knowledge, and because the apparatus was attractive. The experiment on the Coefficient of expansion had the widest range of interest. It appealed to some as being practical; to others as affording new information; to a third group as explaining interesting phenomena; and to a fourth group as "just interesting".

A glance at the table will show that ten out of the twenty-six experiments mentioned come under two heads, the practical and new information. The coefficient of expansion is mentioned by six different students as something of a practical nature. (This experiment heads the list in Table III). The novelty of five different experiments seems to explain why they are interesting. The law of lengths was given by three students, all of whom are musicians. In answering the second question, only one student out of the thirty-three seemed to have been interested in his experimental work because it helped him to answer questions previously raised in his mind.

On the whole the answers to question 2 were fairly satisfactory. They at least lead us to see some of the factors which enter into the experiments, and suggest to us the character of laboratory

exercises of greatest value.¹ Too often high school students are given exercises in the laboratory that possess little real value. Since the time for such work is limited it is very necessary that only those exercises of greatest educational value be regarded.

A great variety of experiences was given in answer to question 3. The answers were so voluminous that only a condensed statement is made of the experiments mentioned first. The experiment of the coefficient of linear expansion was associated with ten ordinary conditions; the siphon and suction pump reminded students of nine every day experiences; melting and freezing recalled experiences in nine cases; the principle of the pulley had been observed by nine students previously; the center of gravity could be associated with former experiences by six; transmission of sound by six; specific heat by six and the conduction of heat six.

All other experiments mentioned in Table III were associated with from two to five different experiences. In cases where the student did not think of some experience at the time of the experiment, he was usually able at the time of the test to give some example.

The answers to questions 5 and 6 will be considered together. All of the thirty-two students have had some other laboratory work except six. The following table shows the number who had certain laboratory work before and the number preferring certain courses:

Course	Taken before	Preferred by
Manual training	15	4
Physics (before)	2	9

1. Coleman's Laboratory Manual was used in class and the Mann and Twiss text.

Drawing	5	1
Biology	6	0
Botany	4	0
Physiology	2	0
Physical Geography	3	1
Zoology	1	1
Cooking	1	0

Some of the reasons for liking manual training are (1) no note books; (2) more practical. Physics was preferred by five because it was practical and by four others because it is interesting. Two think drawing and zoology best, while one prefers physical geography on account of the field trips. Of the six who did not have previous laboratory work, four are among the best students in the subject of physics.

As to the last question in the test seven placed history first; English five; physics nine; mathematics eight; and drawing three; The following subjects were preferred by one student each: Manual training, Latin, trigonometry, physical geography, botany, physiology, and Greek.

The nine placed physics ahead of all other subjects for various reasons, among them being: getting new information, dealing with interesting things, helps to answer Nature's questions, helps in repairing simple machines and is a preparation for engineering. Physics was given second place by four, third place by three, fourth place by three, fifth place by one, sixth place by four and seventh

eighth and ninth place by one each.

Five put English at the head of the list. History four, mathematics eight, and drawing three. Latin, Greek and manual training each headed the list once. Various reasons were given for preferring different subjects. Some were practical, others were liked because they were easy. Two or three liked their subjects because of having good teachers.

In order to test the students as to their ability to recognize physical principles, they were taken on a field trip. The class was asked to note as many examples of the application of physical principles as came under their observation. The examples noted are tabulated in Table V. They are arranged under twelve heads, and each example given is a good illustration of the principle involved. There is little doubt that the list is more extensive than it would have been if made at the beginning of the course in physics. Not that the particular applications of certain principles had not been observed, but that the principle was probably obscure to the observer. The list being made up from the observations of a single field trip is considered very satisfactory.

TABLE V.
PRACTICAL EXAMPLES OF PRINCIPLES OF
PHYSICS NOTED ON A FIELD TRIP.

Pulleys	Inclined Plane
Block and Tackle, In ice plant;	Pulling load up the street.
holding up painter's stage.	Place on which ice was removed.
To raise draught door	Roll of wire being rolled up a grade
Electric light pulleys	Plane to pull buggies up.
Pulley on traveling crane	" " roll barrels
	Slanting platform used to raise freight to a car.
	Load of coal being taken up hill.
	Climbing up stairs at ice plant.
Gas Pressure	Levers
Air brake. Power used in	Controlled coupler on car.
pumping, steam engine.	Windows being cleaned with
Steam pressing against piston.	cleaner on a long stick.
Air compressor in light plant	Levers in an engine. Safety valve.
for passenger coach.	Double tree on a wagon.
	Throttle of an engine.
Composition and resolution of force	Friction
Traveling crane carrying	Axles on cars, wagons, buggies
buckets of ice.	Shoes on pavement.

TABLE V (continued).

Falling Bodies	Equilibrium
Falling of stones.	Chicken standing on one foot
Water falling over pipes.	
Pressure of Liquids	Expansion
Filling water wagon at plugs.	Hot box in engine.
Pumps in ice plant.	Linear expansion on rail-
Suction pumps to raise water from tank to engine.	road track.
Heat	Sound
Freezing water at ice plant.	Wave lengths by piano tuning.
Vaporization by condenser.	Vibrations.
Pouring hot water on ice buckets	
Ice plant covered with frost.	
Absorption of heat by water	
Lowering water to freezing point.	
Moisture gathered on pipes	
Use of asbestos on pipes	
Use of salt to keep water below freezing point.	

CHAPTER IV.

SOME CONCLUSIONS BASED UPON
CONDITIONS AND PROBLEMS.

Physicists are aware that there is so much material and such a short period of time in which to present their subject in the secondary school that some phases must necessarily be omitted. It is a question then of what is of importance in secondary schools. In trying to answer such questions writers have worked out texts and definitions and have planned courses. The results of all trials up to the present are shown in very concise form in the statement of the recently adopted physics unit. This embodies the experiences of physicists for a long period. Tracing the college requirements in physics we note that for some time the tendency has been to make the subject more practical. This no doubt is the best type of physics for the beginner and is the kind that will appeal to him most strongly. If physics can be taught through its practical applications, the student can readily see a reason for studying the subject. He will find physics a live subject and endless in its possibilities. A firm grasp of physical laws will make man a stronger force, because he can intelligently use his own force in directing the infinitely larger ones.

The best way to help the student of physics, then, has been a matter of deep concern. Scientific associations have spent both time and thought in planning the best line of work from the great realm of physics. The mental make-up of the student is quite

as important as the character of the course. Investigation unquestionably bears out the suggestion that the practical, every day physics is the course needed in secondary schools. The formal, stiff, mathematical courses are not calculated to secure the best working knowledge of the subject. Because the question is an all-important one, scientists have felt the call for investigation, and have worked out definite, general courses. The aim is not so much to turn out physicists as to prepare the average student for a better appreciation of the world in which he finds himself. In order that this aim may best be realized the clearest conceptions of physical ideas must be had. Our knowledge of physics must be more than mere bookish ideas. It must be usable and capable of being imparted to others.

From general observation and special tests, it seems that this usable knowledge comes through the ability to see physical principles in their various applications. We walk the street, we travel by rail, we see the far-distant stars, we hear the peal of thunder and are oftentimes unaware of the laws and principles involved in such experiences. The principle involved in getting an image of this printed page on the retina of the eye is exactly the same as the one involved in getting an image of a body at a very great distance, or in getting an image in a camera, and yet these experiences are so commonplace that too many fail to see the identity. We just take things as they come without question. If we will stop for a moment, we can easily think of some things in common use, where the principles involved may be clear in other appli-

cations, but entirely hidden in these. We get into the habit of merely passing things by and never raising a question in our minds about explanations of things seen and experienced. What if we are not called upon to explain our own experiences! It is more than sufficient to explain phenomena to ourselves. It is a satisfaction to be able to explain things observed, the principles of which were at first obscure.

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Michigan Schoolmasters' Club.
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North Central Association of Colleges and Secondary Schools.
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