A STUDY OF THE TRENDS IN THE TEACHING OF SECONDARY PHYSICS

By

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CHAPTER I

INTRODUCTION

I. BRIEF HISTORY OF EARLY PHYSICS

Physics as a secondary school subject had its origin in Western Europe during the twelfth and thirteenth centuries. As a quantitative subject and with the establishment of an experimental basis for the study of the natural phenomena, interest in physics began to grow under the contributions of Galileo and Newton.

The study of astronomy is one whose origin can be traced back almost as far as the earliest times on record. Aristotle (384-322 B.C.) gave a summary of the astronomical theories of his time. He was of the opinion that the earth was spherical and immovable. Pythagoras of Samos (572-497 B.C.) seems to have taught that the earth had a spherical shape and that it poised in space. Hipparchus determined the chief astronomical data—the length of the sidereal year, and the eccentricity of the sun's orbit with accuracy.¹

The influence of the Church holding these views contrary to its interpretation of the Bible, prevented the acceptance

of these new ideas. In the later years of the fifteenth century, the new spirit of inquiry developed into the Renaissance. At that time, science began to take its place in study and has played a very important part in the lives of man and of nations. It is not necessary to relate all the steps in its development, but history alone can reveal the key discoveries that have made many changes in our study.\(^2\)

II. BRIEF HISTORY OF PHYSICS IN AMERICAN SCHOOLS

The development of interest in physics under the subject "Study of Natural Philosophy" had its origin in America in the eighteenth century due to popular lectures and demonstrations. "The nineteenth century saw the introduction of physics in the public high schools. The first one, opened in Boston in 1821 included physics in its curriculum."\(^3\) The work in this school was done without the use of a laboratory. "The first university laboratory of physics was opened by the Massachusetts Institute of Technology in 1867 and this was followed in the high schools by the gradual transition of class demonstrations into individual experimentation. By 1872 physics had so progressed that it was made an entrance requirement of Harvard University."\(^4\) There was little


\(^3\)Loc. cit.

\(^4\)Loc. cit.
uniformity in the attempt to meet this requirement by the secondary high schools until in 1886 when the Harvard Descriptive List was published. This list offered forty experiments to be performed by pupils. This set a criterion in standardizing laboratory content and apparatus. By 1905 we see this move, a good thing, carried too far. Ready-made courses were provided rather than guides which could be used to fit varied cases.\textsuperscript{5}

The teaching of physics aimed at preparation for college rather than toward practical problems. The beginning of the twentieth century witnessed the change from the old dogma of formal discipline, based on the psychological fallacy that the mind is a homogeneous tool, to a reorganized course to fit the changing character of the secondary school population. Within the next decade, nearly every high school text written was entitled, "Practical Physics," with laboratory manuals filled with exercises supposed to have great practical value. The original number of exercises to be performed have been doubled or tripled until the student must skip here and there through the book, leaving half the work undone; and, what he does undertake is so hopelessly tangled up with complicated machines and mathematics that the simple and fundamental principles are completely lost. Even the name of the exercise is taken from the name of the machine rather than the principle involved, such as pulley, wheel and axle, incline plane, convex lens, etc.
A volume could be written showing how manufacturers have preyed upon boards of education in the sale of expensive apparatus. The equipment of the physics laboratory in the high school need not be very expensive; many boys, if encouraged, will be glad to assemble pieces of homemade apparatus as a leisure time project.

Between 1920 and 1925, we saw a wave of enthusiasm for the problem-project methods of laboratory conduct sweeping through the schools. Its aim was to arouse self-initiated pupil activity. The term project was to create a desire to understand the meaning of some fact, a conviction that is worth while and possible to obtain an understanding of the thing in question. George R. Twiss says, "In an ideally arranged course of study the student would go to the laboratory just as a scientist does, to find out at first hand by special appropriate observations and experiments certain essential facts of observation which he needs in the methodical investigation of a scientific problem, and which he cannot so conveniently or effectually find out elsewhere. He differs from the scientist in that he is immature, his knowledge and scientific skill are limited, and he is not trained,—but being trained."\(^6\)

This question of the project method and the formal laboratory procedure are still contending for supremacy. The project method offers vitalization and motivation with emphasis on pupil initiative and activity, while the formal

laboratory procedure offers a method of less intensive study of many problems, which is suited to a beginner and better fitted to instruct members of our present high school population who are not equipped to carry on even amateur research work.

Today in the secondary high school, we see a tendency to swing back to the old lecture method of demonstration instruction with less emphasis placed upon performing all experiments in the laboratory. We find the present population in high school unable to make the application that is needed to make an experiment of value. The depression plays a large part in changing the laboratory set-up.

III. THE NEED FOR THIS INVESTIGATION

Physics in the high school has gone through many changes that are somewhat unnecessary. For instance, when a desired change is made, we wait so long for it to come that we carry it too far before we see the evils it has brought with it. If a study is made of the past trends in physics, we will be more able to guide our adoption of changes in the future.

Realizing that there have been changes and new developments, the writer believes it would be profitable to point out some of these trends as revealed by a study of this nature.

IV. THE PROBLEM

In order to place physics teaching on an economic,
scientific, and usable basis, it is essential that a scientific method be used in the determination of the solution of the many problems that hamper the teacher in his work.

There is a decided need for uniformity and standardization so that every teacher may be able to note progress, have specific aims, and better prepare those students who may not be fortunate enough to attend institutions of higher learning to meet life problems. It will be the effort of the author to point out some of the things that are being done and what should be done to better meet these needs; to point out the most worthwhile phases of the work, by developing functional values, cooperative planning, solving similar problems and placing the study of physics on a more desirable level comparable to other high school subjects.

Research is the chief tool of science. So, as a result of a study of the current literature, texts, courses of study, and special problems dealing with the teaching of high school physics, an effort has been made to determine the practices and trends followed in the presentation of this subject. The author hopes to show some radical changes, as well as the extent to which high school physics should go in order to leave the student with a clear conception of a few of the fundamentals and a chance for further study without a distorted idea relative to science.

V. BRIEF SUMMARY OF THE FINDINGS

The discussion in this section may be summarized as follows:
1. Physics had its origin in Western Europe.
2. Galileo and Newton were its first contributors.
3. Physics was introduced in America as "Study of Natural Philosophy."
4. Popular lectures and demonstrations were the early methods used in presenting scientific facts to the people.
5. In 1872 physics became an entrance requirement to Harvard University.
6. In 1886 the Harvard Descriptive List was published.
7. The Harvard Descriptive List was an aid in standardizing laboratories.
8. No practical problems were used in the early physics texts.
9. Much misuse was made of physics by manufacturers.
10. There were two methods used in the teaching of physics: the Project Method and the Formal Laboratory Method.
11. The old lecture method has been revived in the later years.
CHAPTER II

OBJECTIVES IN HIGH SCHOOL PHYSICS

Professor Hurd of the University of Minnesota says:

"The course of Physics should add to the pupil's knowledge as much as is feasible so that he may use it in his every day life to make him more efficient socially and vocationally. The subject material should bear upon his necessities and his experiences in daily life."¹

Professor Meister says: "The goal of such an education as the generalizations of science have come to function; first, as a body of knowledge which must be experienced and mastered; second, they represent a method of thinking which civilization has had to adopt for its own preservation; third, they insure future progress."²

Dr. A. W. Hurd shows a consensus of opinion on the subject of inadequacies in the teaching of physics:

The greatest need at present is a reorganization based on a more careful selection of subject material to meet the needs of the pupils. We need better teachers trained in the science of child development. We need more carefully defined objectives of instruction.


There should be greater flexibility in our courses with attendant responsibility and freedom of action of pupils. Educational science should dictate future changes in the course.  

The conflict of ideas over the subject matter and methods of physics in the high school, which began many years ago with the substitution of original discovery and extreme quantitative work for the underlying thought of the old-time texts, is being gradually settled and the period of reconstruction is practically here. The question is again one of subject matter and method in view of the prevailing conclusion as to the ends to be reached through the study.

The later years of experience have brought many convictions as to the suitability and unsuitability of subject matter. While our ideas of what should not be taught are perhaps more definite than those of what should be taught, the wealth of proper material to draw upon is greater than ever before, and we need only to use care in selection.

There have been two distinctly opposed schools of thought with respect to the teaching of physics. The old school held essentially that physics was a great quantitative natural science. It was the only science in the high school course; therefore, it should be treated from the quantitative standpoint in order to give students an appreciation of the value of quantitative knowledge and to train them in habits of accuracy and quantitative thinking.

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The new conception, under which we may now feel free to act, is that physics is the science of a great group of natural phenomena by which we are surrounded. It should be the aim of the work in the high school to bring the student into a knowledge and appreciation of these phenomena and to give him power to recognize and deal with them under new or unusual conditions in an intelligent manner. This does not imply that physics is not a quantitative science, but it does mean that the determination of exact, or even approximately exact, relations belongs to an advanced stage of work based upon a proper understanding of phenomena.

Laboratory work should be closely connected with the class recitation, and the pupil should know the purpose of the experiment. It may even be a repetition by the pupil of a class demonstration, though something different might be preferable. No doubt, it will aid in fixing the principle in his mind.

I. PROCEDURES AND TECHNICS

The fact that the teachers of physics are giving attention to the teaching of broad general principles and the development of a desirable attitude makes one feel that progress is being made. One of these broad general principles is the "scientific method", and the author wishes to show how this should be carried out in the teaching of high school physics.
To make teaching effective, we should first decide upon a method to be used. No definite method can be declared the only method, but most science teachers prefer the "inductive." This is the method of discovery—the one science should employ.

Good inductive development should begin with a period of study in which old knowledge is reviewed, interest in the unknown is aroused, aim is decided upon, and the problem is set up. The student should realize that these steps in the procedure are typical to methods used in the solution of the problems in all walks of life. This would aid materially in the transfer desired. The student would be better able to make generalizations, and problems of any nature would become a part of a general scheme rather than isolated facts of one special assignment.

If science is to teach the pupils to learn from laboratory experiments, they must be trained how to pick out essentials from the mass of details, to arrange data in logical sequence, and to draw safe conclusions. If they are to be taught to reason, they must learn the proper technic of comparison. It may also be safely stated here that we are preparing these students for life. No better opening can be offered than that of the physicist, which requires not only special training but a special aptitude, an inquiring type of mind, and an insatiable curiosity.

In studying the work of a physicist, we come to the conclusion that he followed some logical form in setting up
and solving a problem. This is not the rule, for no experiment can be set up as a sharply defined problem when it deals with the unknown. After a discovery has been made, it is easy to state the problem, relate the plan of action used in solution, and then state the results that lead to the discovery. The teacher should set up the same condition for his class. Children think, but they can be trained to think better. They may be given problem situations that seem to be inconsistent. The teacher may criticise their attempts and encourage them to find further information in the laboratory. The success of the students and the teacher depends to a great extent upon the natural interest and practical application of the study.

II. SOURCE OF LIST OF OBJECTIVES

Statements of authors of text books. A brief statement from some work done in the last three years by the committee on the Development of Standards for use in the Reorganization of Secondary School Curricula in the North Central Association of Colleges and Secondary Schools shows the following objectives: health, vocational, avocational, and social. To this list may be added the following: 4

Knowledge:

1. To acquire knowledge which will produce a better understanding of our environment.

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2. To acquire knowledge necessary to correct superstition and erroneous beliefs.

3. To acquire a knowledge of the application of principles in industry.

4. To acquire the knowledge necessary for future courses in science or to prepare for college.

5. To acquire a knowledge to increase the general culture of an individual.

Exploration or orientation:

1. To give the pupil a view of the field of science so that he may explore his interests, capacities and abilities, as a basis for the election of further courses in science, the selection of a vocation, or to find new fields of interest.

Abilities:

1. To develop the ability to think scientifically, to rely on facts, to interpret, observe, gather data systematically, and to do quantitative thinking.

Attitudes: to develop:

1. Attitudes of appreciation of the great men of science and of the contributions of science to man.

2. A desire to understand the meaning of some fact, phenomenon, or experience. This leads to questions and problems.
3. A conviction that it is worth while and possible to obtain an understanding of the thing in question. This causes work with impelling interest.

4. The gathering of books, experiences, and experiments of the needed information to answer the question at hand.

It would appear that a course in physics could be selected that would relate directly or indirectly to one or more of these many objectives. The author proposes that the physics course be divided into units as follows:

Unit I. Hydrometers as illustrative of the applications of the principles and methods of science.

II. Principles of liquid and gas pressure and their applications to water and gas supply systems.

III. What are machines and of what value are they?

IV. Applications of the principles of fluid pressure in water and the aircraft.

V. Heating, ventilating, and humidifying systems.

VI. Refrigeration and other applications of heat energy.

VII. Atmospheric electricity and some of its manifestations.

VIII. Electric lighting systems.

IX. Electric generation and transmission.

X. Electricity in communication.

XI. Electro-chemistry and the storage battery.

XII. Photography and picture projection.

XIII. Telescopes and microscopes.
XIV. Light projectors.
XV. Color and some of its phenomena.
XVI. Musical instruments.
XVII. X-rays and other radiations.
XVIII. Simple manifestations of gravity.
XIX. The automobile and aeroplane.

This unit plan is suggested for most high school pupils who are interested only in the things in their environment, not in the abstract.

It is reported, that during the school year 1928-1929, twelve of these units were given tryouts with thirty-four groups of pupils ranging in number from fourteen to seventy-four in from one to eleven classes in six different schools. The following results were obtained.5

1. Every pupil in every group using this unit made evident progress.

2. There was considerable variation in gains in groups of pupils.

3. There is evidence that pupils tend to have greater ranges of ability after instruction than before.

4. Pupils who have had general science have higher achievement ratings in certain fields.

5. Juniors do as well as seniors in physics if the course is a junior course.

6. There is evidence that the present course in physics contains too much content if greater achievement is to be expected.

Statements made in Courses of Study. First semester.

Unit I. Fundamental Physical Concepts.

1. To recognize the necessity of a system of weights and measures.

2. To become acquainted with metric units of weights and measures and to reduce them to their English equivalents.

3. To recognize by observation some of the fundamental properties of matter.

4. To gain a conception of the molecular theory of matter, that matter is discontinuous.

5. To recognize the fact that scientific theory, such as the molecular theory of matter, is not a mere guess, but rather a rational conclusion drawn from a great number of related observations.

6. To recognize the fact that discoveries of great importance to human welfare have come about as a result of research carried out in an effort to investigate the validity of scientific theory.

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6 Members of the Science department: Physics, Dr. James F. Mackell and Dr. Earland Ritchie, Indiana State Teachers College. State Course of Study in Physics for Indiana High Schools. Bulletin Number 100E. Indiana State Department of Public Instruction. 1933. pp. 150-174.
Unit II. Mechanics of Liquids.

1. To learn that pressure in liquids acts according to specific laws.

2. To learn that liquid pressure and total liquid force are related but wholly different physical phenomena.

3. To become acquainted with some of the common applications of liquid pressure such as are found in hydraulic appliances.

4. To become cognizant of the fact that the application of the laws of hydraulics to city water supply and fire protection which constitute one of man's most useful scientific aids.

Unit III. Mechanics of Gases.

1. To learn how the atmosphere is used to make water and other liquids rise in exhausted tubes.

2. To learn that our atmosphere has weight and exerts pressure.

3. To become acquainted with some of the common applications of the gas laws such as are found in the submarine, blood pressure gauges, balloons, siphons, pumps, etc.

Unit IV.

1. To arrive at a concise notion as to the meaning of the physical concepts of velocity, acceleration, momentum, and force.
2. To become aware of the fact that force and acceleration are inseparable, that one cannot exist without the other.

3. To learn something definite about the life of Sir Isaac Newton and his great contribution to human progress.

4. To learn how the law of gravitation was a great aid to astronomy.

Unit V. Work, Energy, and Power.

1. To recognize the fact that physical work is something which can be measured accurately.

2. To become aware of the fact that nature has stored up abundant supplies of energy for human welfare and that this energy is available for man's work.

3. To become acquainted with some of the simple machines which have been developed for the purpose of doing away with human drudgery.

4. To become thoroughly convinced that nothing is ever gained from nature without effort and that it is never possible by any kind of machine to get more energy out than is put into it.

Unit VI. Heat, Temperature and Heat Transference.

1. To form a clear distinction between heat and temperature.

2. To become acquainted with some of the common methods of measuring temperature.
3. To recognize the fact that water expands uniquely and that to this unique behavior all marine life owes its existence.

4. To recognize the fact that most substances expand with a rise in temperature.

5. To understand the three methods by means of which heat is transferred.

6. To formulate several advantages accruing to human welfare as a result of a knowledge of the nature of heat and temperature.

Unit VII. Heat as Energy, Use of Heat, and Heat Machines

1. To recognize the fact that heat can be measured in terms of specific quantitative units.

2. To learn that a great quantity of heat is involved in a change of physical state and that this is the secret of refrigeration in most refrigeration machines.

3. To become acquainted with some of the common types of heat engines and to compare them with mechanical refrigerators.

Unit VIII. Nature of Sound and Wave Motion.

1. To learn that a vibratory body is necessary for the existence of physical sounds.

2. To learn that sound requires a real medium for its transmission.
3. To learn something about the simple laws of acoustic of buildings.

4. To learn that sound waves may be photographed, reflected, refracted and diffracted.

Unit IX. The Physical Basis of Music

1. To gain a knowledge of some of the common musical scales and to be able to build up the major diatonic scale.

2. To recognize the need for an equally tempered scale and to see how well it fills our needs.

3. To recognize the fact that the diatonic scale permits a wide variation of musical composition due to the fact that there are two half steps.

4. To formulate a clear notion of the idea of musical equality.

5. To make an attempt to discover why musical sounds are pleasing, and why man has chosen music as a form of useful recreation.

Second Semester.

Unit I. Nature of Light: Illumination

1. To obtain a clear notion of the point at issue relative to the validity of the corpuscular and wave theories.

2. To learn something about the life and work of Michelson and Huyghens.

3. To come to a realization that the inverse square law of radiation is one of the most important
laws of physics.

4. To become aware of the fact that a knowledge of illumination is necessary to one who plans school rooms or in fact any kind of rooms where human beings are to be happily located.

5. To become cognizant of the fact that light quantity can be accurately measured.

6. To become cognizant of the fact that light is necessary for life and that, therefore, light is one of nature's great blessings to man.

Unit II. Reflectors, Refractors and Image Formation

1. To learn the laws of light reflection, and to develop the quantitative expression for image formation by mirrors.

2. To gain a clear conception of the nature of refraction of light.

3. To develop the quantitative laws of image formation by lenses.

4. To learn the physical properties of the human eye, and to study its possible defects and their remedies.

5. To become acquainted with the telescope and the microscope, and to learn their physical properties.

Unit III. The Spectrum and Color.

1. To gain a clear conception of the nature of pure color.
2. To learn the cause of dispersion by a prism.
3. To learn what is meant by wave length and frequency of light.
4. To be able to explain the rainbow and related phenomena.
5. To learn from a study of polarization of light what is meant by transverse waves.
6. To come to a realization that a study of spectroscopy is advancing science by leaps and bounds.

Unit IV. The Nature of Magnetism.
1. To learn of the properties of magnets including the laws relating to the forces existing about magnets.
2. To formulate a feasible theory of magnetism.
3. To study the earth as a magnet.
4. To point out many applications and to show how they are essential to mechanical and electrical devices.

Unit V. The Nature of Electricity.
1. To be able to distinguish between positive and negative electricity and to explain these according to the electron theory.
2. To observe the various ways of producing static electricity on bodies.
3. To understand the meaning of electrical conductors and non-conductors.
4. To realize that current electricity is but a charge in motion.

5. To understand the chemical effects accompanying current flow through liquid electrolytes and to understand the nature of the process.

Unit VII. Relation of Electricity to Magnetism.

1. To observe that every conductor carrying a current exhibits magnetic characteristics.

2. To know that a helix of wire carrying a current may be likened to a bar magnet, and that if soft iron be used as a core in the coil, much stronger magnetic properties are displayed.

3. To learn that the electromagnet is an essential part of many useful devices.

4. To study the directions of induced currents and to interpret Lenz's law.

5. To note that currents may be set up in a conductor if it be caused to cut magnetic lines of force. This may be done by moving the magnet or moving the conductor.

6. To realize that a changing magnetic field might be that of an electromagnet caused to vary by a changing current value in the windings of the electromagnet.

7. To know the essential difference between a magneto and a dynamo.
Unit VIII. Electrical Machines and Devices.

1. To realize that a loop of wire revolved in a magnetic field sets up an A. C. current.

2. That a commutator attached to an A. C. dynamo enables one to receive D. C. from the machine.

3. That if electricity is passed through a D. C. dynamo it will run as a motor and do work.

4. To know that an induction motor has no brushes and uses no line current in its rotor. That the rotor current is an induced current.

5. To know why an induction motor gives no radio interference.

6. To understand the working principle of a wattmeter and how to read the meter.

7. To know that larger motors would use so much current when starting that they would be burned up if starting boxes (resistances) were not used in series with them until near full speed.

8. To note that A. C. current can be made into D. C. current by the use of a single shaft machine known as a motor-generator.

9. That all motors act as dynamos and set up current opposing that of the line circuit.

10. To explain why high voltages are used on long transmission lines.
Unit IX. Radio, Radio-activity and Modern Physics.

1. To attempt to learn how a radio works and why it works.

2. To make a study of some common radio receiving circuits.

3. To find out what makes a photoelectric cell work and to realize its possibilities.

4. To learn something about some of the discoveries of modern physics.

5. To study briefly the life history of such great physicists as Millikan, Curie, Marconi, Einstein, Compton, and others.

6. To come to a realization that modern physics is based upon recent discoveries and rational theories, and that there is no conflict between the physics of Newton and that of Einstein.

III. SUMMARY

Starting with the suggestion by the college professors, the North Central Association and a number of high school teachers of science, the author wishes to set up a unit method of instruction that will prove workable and of direct benefit to the student. This method should relate directly to the objectives stated and not be so involved with mathematics or technical terms that the student will become lost and confused in his efforts.
All the work in science should be progressive in nature so that the improvement of the student can be tested effectively.

This testing may be accomplished through the use of the improvement sheet in Physics as devised. This improvement sheet should enhance the teaching of physics, by checking results gained against expectations to determine the progress of student and teacher in presenting the units outlined. The difficulties of the students should be determined by the teacher. A review of the units giving the most trouble will be found necessary.

7 Improvement sheet will be found in the appendix.
CHAPTER III

ANALYSIS OF SPECIAL METHOD BOOKS IN TEACHING OF PHYSICS

In the study of texts that represent definite periods, we will be able to see the trends as offered in the class rooms and laboratory.

The study of physics in 1837 was first discussed under Natural Philosophy. By 1901, physics was defined as the science of matter and energy. In 1906, physics was defined as treating energy and matter in their relations to each other in so far as there was no change in the identity of matter. In 1908, physics was defined as the science of matter and energy. From these different definitions, we see that some change has been made. We may notice the definition for matter—the general name of everything that occupies space or has figure, form or extension. In 1878, matter was defined as anything that occupied space or took up room. In 1901, science was not yet able to tell what matter was, but the balance had demonstrated that it was invariable in amount, whatever form it may be made to assume.

Space—Newton's view: "Space is a real receptacle intrinsically void." Descartes's conception: "Space is the essence of bodily substance or an attribute of substance." Berkeley's view: "Space is a mental construction due to the gradual coordination of sensations, especially of sight and
motion." Kantian view: "Space is an apriori form into which sensuous experience necessarily falls." Aristotle held: "Space is the logical condition of the existence of bodies, that without which bodies could not exist, but itself (space) continuing to exist, when bodies cease to exist." Modern theory, Einstein's supposition: "Space is affected by matter." Einstein gave us a new conception of space. A space which a mass can bend more or less to suit its own shape. It would follow, that space must be curved. There can be no straight lines. When a stone falls to the earth, it follows one of the lines of space tension. The sun has warped space until its paths are definitely marked out. Light is the same; it travels in curved lines.

In pointing out changes, let us notice the methods used in laboratory manuals. In the older ones, much effort was made to verify the laws. The new manuals state the purpose of the experiment as: "To find the specific gravity of a liquid," then the student is directed in his work by statements and questions that lay the work before him. Modern physics would bring these problems close to the daily lives of the pupils. Industry depends upon physics, for physics takes its problems, solves them and gives it new life. The old method of teaching physics would make the student ready for a career as a physicist. The new method would make physics remain an important factor in the later life of the pupil, by giving him discipline and transferable qualities.
The pupil must acquire a scientific method of solving problems. This is not done by didactic teaching of a logical setting forth of the steps. It may be accomplished by repeatedly showing the pupil that this method always gives the quickest solution of the problem.

We can no longer require students to take a subject just for the subject itself with no regard to interest. It is the duty of a teacher to present his subject with a variety to arouse interest. The exacting less important problems are to be omitted, and only those dealt with that relate directly to the student’s surroundings.

I. THE DEVELOPMENT OF THE DEMAND FOR PHYSICAL SCIENCE

In the analysis of any methods book, it is necessary to notice some of the changes the authors had to consider. Natural Philosophy was dropped from the curricula in 1872, and physics took its place as a college entrance requirement.

In about 1880, several questions were asked the heads of various schools, and a bulletin was published by the United States Bureau of Education in which a summary of the replies from 175 public high schools and 433 private secondary schools were discussed. The questions asked for information as to the time of introduction of the course in physics, the number of periods a week devoted to it, the text used, the method of work, the amount of laboratory equipment, the amount of time devoted to laboratory work, whether or not the pupils themselves did any laboratory work, and whether there were class experiments by the teacher.
At that time Pittsburgh, Worcester, Punchard Free School at Andover, and the Friends Select School at Philadelphia were the only secondary schools in which a full year's work was offered. Two public and seven private schools reported shorter courses with laboratory work by the pupils; thirty-eight public and twelve private schools reported a full year's work with experiments by the teachers; fourteen public and ninety-five private schools reported one year or less of textbook work only; and seven public and six private schools reported no physics at all.

The most popular text was Steel's *Fourteen Weeks in Physics* which was used in thirty-four public and one hundred sixteen private schools. Next was a text by Quackenbos used by fifteen public and seventy-one private schools.

In 1884, it was generally decided that the method to be used in the teaching of physics was to be inductive. This method met with many difficulties because the teacher knew little or nothing about it in his own education. If he taught mathematics, he was especially familiar with the deductive methods and found it hard to change. The progress of the student by the inductive method was slow which discouraged many.

Later, we find the Harvard Descriptive List published. This was a list of laboratory experiments to define the laboratory work that was required as a part of the course acceptable for admission credit at that institution. The
The purpose of this list was an attempt to bring together such experiments as would have the most frequent and important applications in ordinary life.

The objects sought were first, to train the young student by means of tangible problems requiring him to observe accurately, to attend strictly and to think clearly; second, to give practice in the methods by which physical facts and laws are discovered; third, to give practical acquaintance with a considerable number of these facts and laws, with a view of their utility in thought and actions of educated men.

The influence of the Descriptive List on the development of physics teaching in America was very great. Coming when it did, it exalted the demand for objective teaching into a requirement of quantitative laboratory work. Teachers and school boards were taught how a laboratory method of teaching could be introduced into the work in physics with the use of materials at hand. It insisted on careful, neat work, and its firm stand for work of a scientific character made its effect on physics teaching last for many years.

The Committee of Ten, at a Conference of Physics, Chemistry, and Astronomy recommended that, "physics be pursued the last year of the high school course, in order that the pupils should have as much mathematical knowledge as possible to enable them to deal satisfactorily with the subject. That physics be required for admission to college, that it be taught by a combination of laboratory work, textbook, and thoroughly didactic instruction, that the laboratory work

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should be largely quantitative and that the aim of the teaching should not be to make a so-called rediscovery of the laws of physics but that the pupils should determine the elasticity of bending wood as to length, breadth, and thickness and see if the results agree with the laws.\textsuperscript{2}

The North Central Association of Colleges and Secondary Schools in 1907 issued a topical syllabus which contained topics to which no objection was made by any of its fifty-five members. It contains eighty-one topics concerning the essentials of a high school course in physics at the present time. This relatively small number of topics allows possibilities for the variation of courses to suit local needs. It furnishes a basis for college entrance and subsequent work in college in further study of physics.

This syllabus is important because of what it omits. When used by a teacher, as suggestive but not binding, its effect may be very good, but authorities outside the school have not let it function in this way. Teachers know that it is necessary for their pupils to make a good showing at examination time, and as a result, they feel compelled to cover every topic at any cost. Working thus, with a prescribed syllabus, limits the teacher’s initiative and discourages research methods. In nearly every case, too much is prescribed, and this prevents sufficient attention to the scientific method of inquiry.

\textsuperscript{2}Ibid., p. 54.
The methods now used in teaching fail to encourage a large number of students to elect physics. When the student takes up the study of physics, he strikes at the very beginning of impossible definitions and mathematical statements of laws which mean nothing to him. He has nothing in common to hitch his physics to, and he is immediately cut off from securing a discipline that may be of great value to him outside of the physics classes.

Bagley says, "What I carry from my school work to my farm work is not a generalized habit of work but a generalized ideal of work." Since a scientific habit of mind, when developed in physics is not transferable, while a conscious ideal of scientific method is transferable, it is important to note the distinction between a habit and an ideal. The ideals which physics should foster are those of suspended judgment, open-mindedness, just weighing of evidence, impartial observation, impersonal judgment, and trying to get at all the facts.

II. PHYSICS AND ITS RELATION TO DEMOCRATIC EDUCATION

The purpose of education in a democracy is to better human relationships. The type of government we have must fail or succeed through the efforts of education, for it has as its basis informed and intelligent citizenry. When a crisis comes, we stop and make a weak effort to check up on

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our various systems, or replace them with different ones. We find that science has done much in making changes in business methods, in modes of travel, in communication, and in government, but little use has been made of it in solving social problems.

The teachers of science have a distinct advantage in presenting physics in the secondary school, but they are slow in realizing the advantage. A student can be taught to approach social problems in the same manner he learns to solve problems in science. In many fields of science, rapid progress has been made which exerts a profound influence upon human thought and action. It is said that Henry George went to an American College to explain his economic theories to the economists, but he found that the scientists were the only men that could understand his plan. It would appear that their training gave them advantage in understanding principles in other fields. The technic acquired in solving problems in science can be used in the social field.

The scientific mind has produced instruments to understand the universe, cosmic rays, ways of extending life, polar explorations, mysteries of the deep sea, but it halts when it comes to social and economic problems of a life it has produced. We hope that scientific methods may be extended and the minds of young people may be developed so emotions and prejudices will not hamper them in solving problems of society.
Man persists upon the earth due to the fact that he has mental ability to adjust himself in spite of his physical handicaps. He has ability to plan his future, but at present his social planning has been colored by too much individual selfishness.

III. PRACTICAL APPLICATION

It seems rather unnecessary for a detailed discussion of the practical application of science, but if the secondary school student is to study science, he must see a use for it.

Our pleasures, our existence react on every hand with tools of science. The thing we are most interested in now is "How can this tool be used to bring necessities of life?" The answer is to produce a need for the instruments given by science. We can not sit and wait for everything to come to us. Electricity is taking the place of servants, so let science be applied to a greater extent. Let our students learn to use it earlier in life.

Physics is related to life in many situations. The home, the street, the school, and all industries are rich with elements common to physics and daily life. The teacher can use cook stoves, furnaces, fireless cookers, refrigerators, houses, clothes, frost, dew, drying, sunshine, smelting, forging, matches, sparklers, fireworks, firearms, putting out fires, and a number of other topics as examples to bring his work close to the lives of his students.
Dewey says, "There is no difference of kind between the methods of science and those of the plain man. The difference is the greater control in science of the statement of the problem, and of the selection and use of relevant material, both sensibly and ideally."  

There is a degree of refinement the plain man lacks which offers the physics teacher a great opportunity. He has a chance to help refine the thinking of the plain man until it becomes scientific. If the pupils begin their study of physics in the method accustomed to the plain man and are led on to more critical and impersonal habits of thought, it tends to preserve common elements of method. The more these common elements are preserved the greater is the transferable value of the teaching.

Questions not suitable. The volume of a certain mass of hydrogen is 250 c.c. under pressure of 800 mm. of mercury. What is its volume under standard pressure of 760 mm? If a body moves with uniform velocity of 10 cm per second for 20 seconds, how far will it have traveled? A body starting from rest acquires in 5 seconds with a uniform acceleration, a velocity of 4800 cm per second. What is its average velocity? The weight of a certain mass is 84 gm. What is its weight expressed in dynes? What is the length of a seconds pendulum

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whose gravity acceleration is 978 cm per second per second? How many joules of energy does a kilowatt hour represent? What is the velocity of a body having uniform accelerated motion at the beginning of the T second. Solve for (a) and (T). Using the formula for free falling bodies and that for work, prove that the expression of kinetic energy should contain velocity squared. Two forces of six and eight dynes respectively act at right angles to each other on a mass of 2 grams. What is the resultant force? What is the kinetic energy at the end of 3 seconds? A brass rod is 50.8 cm long at 20°C and 59.886 cm long at 98°C. Find the coefficient of linear expansion of brass.

These questions are not suitable, for they require an exactness of formula recall that has little practical value. The student is expecting, as a rule, a more general application of the knowledge he has acquired.

Suitable problems. Does it require more work to slide a cake of ice up an inclined plane than it does to lift it vertically through the same height? If so, how much more? How can you alter the inclined plane to increase its efficiency? Can the ice be lifted into the ice house more efficiently with a set of pulleys than with an inclined plane? Does it require more work to lift a stone with a crowbar than to raise it by hand through the same height? How much more? Is a given motor more efficient on a tap in the basement than one on the third floor? Is there any
relation between pressure and efficiency? Which kind of coal in your town gives the greatest number of heat units per pound? What is the efficiency of a small gas engine? Are the object and image formed by a lens closer together when both are of the same size than when one is larger than the other? Does it cost more per hour to light a room to a given brightness with candles than with oil? In your town is it cheaper to light houses by electricity or by gas? How much? What is the specific gravity of the milk furnished by your milkman? Is it up to standard? Which is the best kind of wire to use in making electric toasters?

Vital problems. What is the correct position in dismounting from a moving car? Why? Why does an automobile tear up the surface of the road more than a team and wagon? Why do you stand in a moving car with your feet apart? Why are there door knobs on doors? When you shovel coal, do you pull up on with your left hand as hard or harder than you push down on its handle with your right? Why? When you sweep a rug with an ordinary broom, does each hand do half the work? If not, show which hand does the more. How much work do you do when you go up a flight of stairs ten feet high? When you come downstairs, do you get back the work done going up? How? Why does lowering the handles of a wheelbarrow make it easier to go over a bump? Why do raindrops make inclined streaks on the windows of a railway car? In which direction do the streaks slope when the car
is moving east? If you weigh 125 pounds and can just float with your nose out, in fresh water, what is your volume? Could twenty-five horses make an automobile go as fast as a twenty-five horse-power engine? Why? What makes a wood fire snap and crackle? Why can vegetables be cooked more efficiently in a fireless cooker than on a red hot stove? What prevents a pond from freezing solid? Which cools faster, a cup of hot tea or the tea that remains in the teapot? Why? What is the dew point directly under the lid of a kettle of boiling water? Why does the air escaping from the valve of a bicycle tire feel cool? How many pounds of coal does your furnace burn daily? How many B. T. U.'s of heat are liberated in the house per day? How many foot pounds of energy does this represent? Why can a bird perch without harm on electric wires? Why is the "third rail" dangerous while the rails of an ordinary trolley track are not? Can you light a Christmas tree with 6-volt lamps if the only current available is the 110-volt city current? How? Why does clapping your hands make a noise while waving them does not? Why should colors that are to be worn in artificial light be selected in the same kind of light? Does placing a red shade over an alcohol flame colored with salt make people look less ghastly? Why? What makes the colors in a soap bubble? Why has no one ever found the pot of gold that lies buried at the end of the rainbow? Where is the end of the rainbow? Is the air current made by a fan cool?
Is that the reason for having a fan? Which is heavier, a pint of cream or a pint of milk? Raindrops are coming straight down. Will a car standing still or one moving rapidly receive in one minute the greater number of drops on its roofs and sides? Is air drawn up a hot chimney or is it pushed up? Since it is possible for a person to float in fresh water, why is it possible for him to sink? A cylinder and a cone equal in base and in altitude rest on a plane surface, which is harder to tip over? Why? A magnet attracts two iron nails. If the magnet is removed, will the nails attract each other? Is it harder to keep your hands clean in the winter than in the summer? Why? How many surfaces, corners, and edges has a cube? Which has the greater surface, a cube 10 inches on edge or a sphere 10 inches in diameter? Does an iron ball weigh more when it is hot than when it is cold? Is an incandescent lamp filament on fire? Will a ship that will just barely float in the ocean float on Lake Erie? Why? Will a pound of popcorn gain or lose weight or stay the same after it has been popped?

IV. SUMMARY

With all the changes and developments that have taken place, the practical application is the most valuable to society.

We are beginning to learn that setting the unnecessary problems before the student adds little to his general ability.
He learns to look upon the entire field as unprofitable and strives to gain information from coming in contact with the phenomena of nature unassisted. It is time science teachers present the problems and encourage the students in raising questions which will introduce those principles that can build him a foundation for assuring future happiness and understanding. Doubt and superstition undermine many a sound principle of science. It places education on a premium too high for the average citizen to hope for. Man is not measured by what he knows, but his ability to remove obstacles from the ascending paths broadens his horizon of knowledge and kindles his desire to search for truth.
CHAPTER IV

ANALYSIS OF TEXT BOOKS IN SECONDARY PHYSICS COVERING THREE PERIODS OF DEVELOPMENT

I. 1890 TO 1905

Typical Books of This Period. (1) School Physics, Elroy M. Avery. This book is divided into chapter units dealing with matter, mechanics, acoustics, heat, radiant energy, and electricity and magnetism.

The divisions of the chapter on matter are: domain of physics, divisions of matter, properties of matter, and conditions of matter. These topics require fifty-six pages of the text.

The subdivisions of mechanics are: motion and force, work and energy, gravitation, falling bodies, pendulum, simple machines, mechanics of liquids, and mechanics of gases. These topics occupy one hundred forty-four pages.

Acoustic subdivisions are: nature of sound, velocity, reflection and refraction, characteristics of tones, vibration, and laws of vibration. These topics require sixty-nine pages.

Heat subdivisions are: nature of heat, temperature, production and transference of heat, effects of heat, measurement

of heat, and relation between heat and work. These topics require forty-two pages.

Radiant energy is subdivided into: nature of radiation, light, velocity and intensity, reflection of radiant energy, refraction of radiant energy, spectra, chromatics, etc., interference, diffraction, polarization, and a few optical instruments. These topics occupy one hundred pages.

Electricity and magnetism subdivisions are: general view, electric generators, electromagnetics, induction, electrical measurements, some applications of electricity, and electromagnetic character of radiation. These topics require one hundred eighty-nine pages.

Organization. The discussion and illustrations follow each other in regular order throughout the chapters with well-planned figures supplementing the work.

At the end of each chapter, we find a great number of problems but too few questions that would require the pupil to think for himself.

The units follow each other in the usual order with much greater effort being spent on some topics than on others.

Method. The elementary lessons of this book are presented with the intention of building to what the student already knows, and to save his laboratory practice from degenerating into chaotic waste. It is hoped that the student having obtained such a start will, in later years, be guided over more rugged material into advanced realms of achievement.
Findings. This book is filled with details and problems intended to give the student plenty of experience in problem solving. It is the intention of the author to meet the growing tendency in laboratory methods. He does not feel that the student should be left to rediscover the truths known to modern science, but rather that these should aid the student in overcoming the anticipated obstacles and leave the more difficult truths to the technological school.

Professor Avery has made an effort to prepare a book that will aid in the introduction of the pupil into a new world, give him a few elementary lessons, and leave the rest to others. He states that his book can not take the place of a live teacher, but it will be an aid in the field. Each pupil is expected to perform as many laboratory exercises as possible. His classroom work is to be kept ahead of the laboratory work. That is, the pupil must have been exposed to the principles involved before he makes an effort to work them out in the laboratory.

An effort was made by the author to select experiments and exercises that might be performed with simple and inexpensive apparatus. The book is filled with impressive figures and diagrams that aid greatly in interpreting the printed page to the high school pupil.

The units discussed are few, but they are handled in full detail, both objectively and subjectively.
The unit on molar dynamics is subdivided into: force and momentum, gravitation, properties of matter, dynamics of fluids, and energy of mass-vibration. These units are further subdivided, and the total unit occupies eighty-five pages.

The unit on molecular dynamics deals with the theory of heat, which is subdivided into sources of heat, temperature, thermometry, calorimetry, effects of heat, fusion, vaporization, methods of producing cold artificially, hygrometry, and diffusion of heat. This unit occupies seventy pages.

The units on ether dynamics are: radiant energy, electrostatics, and electrophysics. Each unit is subdivided, and the total unit occupies two hundred ninety-three pages.

Organization. This text is organized with sufficient material to include a high school course and such additional material as more apt students demand. The exercises do not have to follow each other, but some may be omitted without loss of unity. The text is divided into three parts, each of which is made up of essential fundamentals.

Method. The author believes that meager information results in a hazy comprehension and provokes meager interest.

Direct and full discussion is given to insure interest and a chance to develop the initiative of the high school student. Full opportunity is offered for continued study.

A number of diagrams, pictures, and illustrations are given for the purpose of assisting the teacher and student in understanding the principles discussed.

Findings. This book was published in order to meet the demands of esteemed critics for a more complete text that would keep up with the methods of presenting such subjects as electricity and magnetism.

There is an effort to do more than prepare a primer of science. The scientific activity of the age requires the addition of new facts to the theory of physics and its application. This makes the material covered by this text very extensive.

The author felt there was a particular need for illustrative material of concrete applications of general principles, which would be sufficient to make clear these principles and indicate the inductive processes by which they have been reached and the deductions to which they lead. Full and varied treatment, by presenting different points of view, clears the conceptions, provokes interest, and allures to continued study. Too much in a text book is preferable to too little.

The book is set up in two sizes, the large one is intended for high school work and the small one for the advanced
course. The advanced courses are not intended to meet the requirements of a technical scientific course in the higher institutions, but they provide added information for the special apt student to develop farther than the average pupil is inclined to go.

This book is not a laboratory manual, but the teacher is expected to supplement the text with references for laboratory work. Experiments are introduced for the purpose of illustrating principles and laws, but tedious details which would tend to distract the students' attention from the leading facts have been omitted.

II. 1905 TO 1925

Typical Books of This Period. (1) *A High School Course in Physics*, Frederick R. Gorton. A study of this book shows it is divided into chapters with the following unit topics: motion, velocity and acceleration, laws of motion-force, work and energy, gravitation, machines, mechanics of gases, sound: its nature and propagation, sound: wave frequency and wave form, heat: temperature changes and heat measurement, heat: transference and transformation of heat energy, light: its characteristics and measurement, light: reflection and refraction, light: color and spectra, electrostatics, magnetism, voltaic electricity, electrical measurements, electro-magnetic induction, and radiations.

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The chapters are subdivided as follows:

(1) Laws of motion-force: discussion of Newton's laws, concurrent forces, moments of force-parallel forces, resolution of forces, and curvilinear motion.

(2) Work and energy: definition of units of work; activity, or rate of work; potential and kinetic energy; and transitions of energy.

(3) Gravitation: laws of gravitation and weight, equilibrium and stability, the fall of unsupported bodies, and the pendulum.

(4) Machines: general law and purpose of machines; the principle of the pulley, lever, and the wheel and axle; and efficiency of a machine.

(5) Mechanics of liquids: force due to the weight of a liquid, force transmitted by a liquid, Archimedes' principle, density of solids and liquids, and molecular forces in liquids.

(6) Mechanics of gases: properties of gases, pressure of the air against surfaces, expansibility and compressibility of gases, atmospheric density and buoyancy, and applications of air pressure.

(7) Sound: its nature and propagation: origin and transmission, nature, intensity, and reflection; wave frequency and wave form: pitch of tones, resonance, wave interference and beats, the vibration of strings, quality of sounds, and vibrating air columns.
(8) Heat—temperature changes and heat measurement: temperature and its measurement, expansion of bodies, and calorimetry, or the measurement of heat; transference and transformation of heat energy: change of the molecular state of matter, the transference of heat, and relation between heat and work.

(9) Light—its characteristics and measurement: nature and propagation of light, rectilinear propagation of light, and intensity and candle power of lights; reflection and refraction: refraction of light, reflection by curved mirrors, refraction of light, lenses and images, and optical instruments; color and spectra: dispersion of light, color, spectra, and interference of light.

(10) Electrostatics: electrification and electrical charge, electric fields and electrostatic induction, potential difference and capacity, and electrical generators.

(11) Voltaic electricity: production of a current-voltaic cell, and effects of electric currents.

(12) Electrical measurement: electrical quantities and units, electrical energy and power, and computation and measurement of resistances.

(13) Electro-magnetic induction: induced currents of electricity, dynamo-electric machinery, and transformation of power and its applications.

(14) Radiations: electro-magnetic waves, conduction of gases, and radio-activity.
Organization. The material presented in this text is presented with the intention of expanding the contacts of the everyday life of the pupil. The teacher is to act as a guide, stressing each phenomenon and law.

It is the intention of the author to point out the service that has been afforded mankind by a knowledge of science. A large portion of the subject matter deals with knowledge that the high school student already possesses, but he is led to feel interested because the information gained here is made to have some value.

The book is free from difficult uses of algebraic and geometric principles, which are often too difficult for some students.

Method. Each unit has been plainly set off and references to related material have been inserted. The exercises have been carefully graded and fit into concrete cases. Problems in pure formula reduction have been omitted. Illustrative solutions of problems and suggestions have been given to aid the student through difficulties.

Findings. This text is simple, being free of unnecessary difficult algebraic and geometric principles. First place has been given to the study of phenomena and mathematical expressions. That author believes in the use of a sufficient number of individual laboratory exercises to fix the principles and phenomena in the minds of the students.
The author has further made an effort to use the various topics recommended by the Committee of Secondary School Teachers of the College Entrance Examination Board.

(2) *Physics with Applications*, Henry S. Carhart and Horatio N. Chute.⁴ This text is divided into unit chapters as follows: introduction, molecular physics, mechanics of fluids, motion, mechanics of solids, mechanical work, sound, light, heat, magnetism, electrostatics, electric currents, electromagnetic induction, and dynamo-electric machinery.

The unit parts of induction are: matter and energy, properties of matter, and physical measurements.

Molecular physics is subdivided into the following topics: surface phenomena, and molecular forces in solids.

The units of mechanics of fluids are: pressure of fluids, bodies immersed in liquids, density and specific gravity, pressure of the atmosphere, compression and expansion of gases, and pneumatic appliances.

The units of motion are: motion in straight lines, curvilinear motion, and simple harmonic motion.

The units of mechanics of solids are: measurement of force, composition of forces and of velocities, Newton's laws of motion, gravitation, falling bodies, centripetal and centrifugal force, and the pendulum.

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The units of mechanical work are: work and energy, and machines.

The units of sound are: wave motion, sound and its transmission, velocity of sound, reflection of sound, resonance, characteristics of musical sounds, interference and beats, musical scales, vibration of strings, vibrations of air in pipes, and graphic and optical methods.

The units of light are: nature and transmission of light, photometry, reflection of light, refraction of light, lenses, optical instruments, dispersion, color, interference, and diffraction.

The units of heat are: heat and temperature, the thermometer, expansion, measurement of heat, change of state, transmission of heat, and heat and work.

The units of magnetism are: magnets and magnetic action, nature of magnetism, the magnetic field, and terrestrial magnetism.

The units of electrostatics are: electrification, electrostatic induction, electrical distribution, electric potential and capacity, electrical machines, and atmospheric electricity.

The units on electric currents are: voltaic cells, electrolysis, Ohm's law and its applications, heating effects of a current, magnetic properties of a current, electro-magnets, and measuring instruments.

The units on electromagnetic induction are: Faraday's discoveries, self-induction, the induction coil, radio-activity, and electrons.
The units on dynamo-electric machines are: direct current machines, alternators and transformers, electric lighting, the electric telegraph, the telephone, and wireless telegraphy.

These units are rather uniform in the number of pages used in their presentation. The most attention is given to mechanics of fluids, with 52 pages, light with 66 pages, and electric currents occupying 40 pages.

Organization. The author of this text places the fundamental principles foremost and emphasizes numerous interesting commercial applications. This is intended to make the student look forward to the study of science.

The material in this book has been organized with the intention of giving the student a firm foundation for future work.

Method. This foundation is built through the use of scientific statements which become fixed in the students' minds as a result of studying simple, practical questions and numerous elementary problems.

The book has simple and direct language, short sentences, careful explanations, and direct definitions. An inductive development of each principle adds to the simple presentation of the material.

Findings. The illustrations and pictures present a very effective method of holding the interest of the student. The
teacher is aided materially by the method used in leading up to each unit.

Little effort has been made to add extra material to the text for the more apt students, but the essentials are emphasized. Due to the publication date of the text, the electrical illustrations seem to be quite out of date.

III. 1925 TO 1935

Typical Books of This Period. (1) The New Physics in Everyday Life, William D. Henderson.⁵ This book is not divided into units but into chapters, as follows: fundamental physical concepts, mechanics of fluids, molecular mechanics, mechanics of solids, heat, magnetism, static electricity, current electricity, magnetic and heating effects of a current, electromagnetic induction, alternating currents, electromagnetic waves, sound, light, and electrical radiations.

These chapters are subdivided as follows:

(1) Fundamental physical concepts: matter, energy and force; the forces of nature; gravity and weight; household measurements; industrial processes; and fundamental metric and English units.

(2) Mechanics of fluids: properties of fluids; pressure exerted by liquids; water power; Pascal's law and its application; Archimedes' principle; density and specific gravity;

atmospheric pressure; the barometer; Boyle's law; pumps, air and water; and household and industrial applications.

(3) Molecular mechanics: molecular forces in fluids, kinetic theory of gases, surface tension and capillary action, molecular forces in solids, elasticity, and Hooke's law, stress and strain.

(4) Mechanics of solids: motion; velocity; acceleration; units of force; composition and resolution of forces; airplane; curvilinear motion; pendulum; work, power, and energy; units, gravitational and absolute; moment of a force; law of machines; mechanical advantage; mechanical efficiency; and applications of the simple mechanical powers.

(5) Heat: temperature; thermometers; quantity of heat; specific heat; laws of Charles and Gay Lussac; absolute temperature; melting; boiling, vaporization, conduction, convection, radiation; refrigeration; heating systems; fuels; heat of combustion; ventilation; relation of humidity to health; heat and work; heat engines; and engine efficiency.

(6) Magnetism: properties of magnets; laws of attraction and repulsion; magnet field; magnetic induction; and terrestrial magnetism.

(7) Static electricity: electrification; electron theory; laws of attraction and repulsion; electron potential; condensers; and lightning.

(8) Current electricity: voltaic cells; electromotive force and difference of potential; electrolysis; storage batteries; and electrical units.
Magnetic and heating effects of a current: magnetic effects, measuring instruments, Ohm's law, resistance, methods of joining cells, electric heat and power, and electric lighting.


Alternating currents: production of A. C. current, cycle and phase, inductance and capacitance, power in an A. C. current, A. C. motors, A. C. measuring instruments, transformers, and rectifiers.

Electromagnetic waves: origin and properties of electromagnetic waves, wireless telegraphy, radio, and television.

Sound: nature of sound, transmission, reflection and refraction, architectural acoustics, intensity and loudness, resonance and interference, pitch and music, quality of sound, vibration of strings, pipes, speech and hearing, and analysis of musical sounds.

Light: nature of light, velocity, intensity, reflection and refraction, artificial light.

Electrical radiations: cathode rays and x-rays, radio-activity, Becquerel rays, radium, and application of radium.

Organization. This text uses the following methods of presentation: (1) Historical method of approach to major
subjects, (2) Familiar phenomena and fundamental principles, (3) Illustrative and explanatory exercises, (4) Practical applications, (5) Review exercises.

**Method.** The author uses the known knowledge of the student or the phenomena familiar to each student as bases for his discussions of the fundamental principles.

The illustrative and explanatory exercises aid in clarifying and interpreting the laws involved in physics. An effort is made to make the practical principles the important part of the text.

**Findings.** Mr. Henderson has written a new book, all of which is easy for the average student to master. The review exercises give the teacher an objective method of checking the progress of the students and the teacher's ability to put the work before the students. This book is almost self-explanatory to the majority of the students. A good teacher can make the work very effective.

(2) **Modern Physics,** Charles E. Dull. This text is divided into unit chapters as follows: introductory matter--weight and measures; mechanics of liquids; mechanics of gases; molecular physics; force; motion; work, power, and energy; machines; heat, thermometry; heat, expansion; heat units, change of state; heat, methods of distribution; heat and work,

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steam engine and gas engine; sound and wave motion; sound, music; nature, velocity, and intensity of light; reflection of light, mirrors; refraction of light, lenses; light, optical instruments; dispersion of light, color; magnetism; static or fractional electricity; voltaic cells, current electricity; effects of the electric current; electrical measuring instruments; induced currents; electro-magnetic induction; radio, x-rays, radio-activity; and the automobile and airplane.

These chapters are subdivided when the material is discussed in the book. Each division is given a topic number which is printed in bold-face type.

**Organization.** The topics are presented as follows: (1) some historical references or familiar illustrations are used, (2) the principle is stated and explained in language familiar to the average high school student, (3) the practical applications are used to develop the principle and to show the students how it touches their lives, (4) the illustrations are used to clarify the more difficult parts of this text.

**Method.** The point of view of the student is kept in mind. Simple language is used, yet full enough are the discussions to bring out every essential point to the student.

Many thought-provoking questions are given, and many problems of varied degrees of difficulty are presented to keep both the slow and the apt student occupied.

**Findings.** The illustrations present a very effective method of bringing to the minds of the students those principles which are difficult to describe in words.
The author has included a solution for each type of problem to guide the student in his work. It is not the intention of this author to present catch questions or bewildering solutions to hinder the student's progress.

(2) Physics for Secondary Schools. Oscar M. Stewart, Burton L. Cushing, Judson R. Towns. These authors intend for this book to meet the demands of the teachers who desire a text which is not too technical, yet, one which has been written in a scientific spirit. Methods and materials which have been found too difficult for the average high-school student have been omitted.

There has been an enormous commercial development in the field of sound reproduction. This has caused the introduction of many new applications of physics to attract popular attention and arouse interest in the subject.

This text has placed special emphasis on motivation of an indirect nature and worth while information. An effort has been made to correlate all the phases instead of treating them as six separate subjects as: Unit I, mechanics and properties of matter; Unit II, heat; Unit III, magnetism and electricity; Unit IV, waves in matter, sound; Unit V, light waves; Unit VI, electrical emissions and waves.

These units are divided into chapters as follows: (1) Mechanics and properties of matter: science and physics;

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simple machines for transmitting force; some properties of water and other liquids; some properties of air; addition of forces; some effects of molecular forces and motion; motion and force; and work, energy and power. (2) Heat: temperature and expansion, transference of heat; measurement of quantity of heat; melting and freezing; evaporation and humidity; heat and work; and heat engines. (3) Magnetism and Electricity: magnetism; charges of electricity; the electric current; magnetic, mechanical, and chemical effects of currents; electrical energy and power; electromotive forces induced by magnetic fields; and alternating currents. (4) Waves in Matter, Sound: wave motion and sound; musical sounds; and reproduction of sound. (5) Light waves: nature of general properties of light; regular reflection and the formation of images in mirrors; refraction and optical instruments; dispersion and color phenomena; and the nature of light. (6) Electrical Emissions and Waves: conduction of electricity through gases; electronic emissions; and electrical waves and radio communication.

**Organization.** These units are quite exclusive and no one unit receives more attention from the author than the other. One of the outstanding features of this book is the questions that are printed at the beginning and at the close of each chapter. The questions at the beginning of the chapter are intended for general discussion, by both the students
and teacher, to form an idea of the students' general knowledge of the subject, and to develop a certain degree of curiosity. The questions at the end of the chapter are to test the students' acquired knowledge. No effort is made to generalize until a specific background of knowledge has been given the student.

**Method.** This text has a great number of teaching aids, such as objective thought questions, problems involving quantitative applications, and assignments for investigation or observation. The most important points in each chapter are restated in a summary. The problems or questions are not all intended for any one class; a choice to meet individual differences is intended.

**Findings.** The use of italics indicates the presence of technical terms (acceleration, work, efficiency), algebraic equations, and essential definitions.

The author intends that this text be used in the high school, accompanied with suitable laboratory work and classroom demonstration of experiments.

**IV. SUMMARY**

The following graphs show the per cent of space and the emphasis placed upon the different units by the various authors.
FIGURE I

WEIGHT AND MEASURES
FIGURE II

MECHANICS OF LIQUIDS
FIGURE III
MECHANICS OF GASES
FIGURE IV
MATTER AND MECHANICS OF SOLIDS
FIGURE V

GRAVITATION
FIGURE VI

MOLECULAR PHYSICS
FIGURE VII
MOTION, FORCE, MOMENTUM
FIGURE VIII

WORK, POWER, ENERGY.
FIGURE IX
SIMPLE MACHINE
FIGURE XI
SOUND
FIGURE XII
LIGHT

Per cent of space
FIGURE XIII
MAGNETISM
FIGURE XIV

ELECTRICITY
FIGURE XVI

AUTOMOBILE OR GAS ENGINES
FIGURE XVII

AIRPLANE
FIGURE XVIII

RADIO-WIRELESS, TELEVISION
FIGURE XIX

X-RAYS, COSMIC RAYS, CATHODE RAYS
CHAPTER V

ANALYSIS OF LABORATORY MANUALS IN PHYSICS

I. EVOLUTION AND DEVELOPMENT THROUGH THE ABOVE PERIODS

C. F. Hagenow, in his article, "Modern Physics," relates a few of the more remarkable developments that have taken place through the periods studied.¹

These changes have had a direct effect upon the text books and manuals. We have changed from a school that presents facts to be learned to a school whose graduates will be able and anxious to obtain facts and solve life problems. The ready-made opinions will be of little value, for their training in the collection and interpretation of facts made them capable of arriving at an intelligent conclusion.

Many of our later laboratory manuals attempt to present the work in too attractive a manner. Students do not grow by having all their work done for them. The teacher must set the problem, not do the work and explain the steps. That might save time, but no permanent effects are obtained. Too many of our books and teachers indoctrinate their pupils. This takes away the thrill of individual accomplishments.

II. TOPICS PRESENTED FOR LABORATORY WORK

Physical Laboratory Manual, by H. N. Chute. The effort to combine practical work and the laboratory manual in the same book has not proved a success. The author of this text has written a guide to be used for laboratory work. He says, "Before a student is fitted for experimental investigation he must have a clearly defined idea of what it is that he is to do, and how he is to do it; what he is to expect, what errors are to be guarded against, and how he is to use the results obtained. This requires that he should come to the laboratory well grounded in the first principles of physics as presented in some elementary treatise on the subject, and well read, especially on the subject that he is to investigate, both as to mode of conducting the work and manner of observing."

In this text, the author states the problem, lists the apparatus to be used, and discusses a method of procedure. In a later text published in 1913, to be used to accompany Physics with Applications by Carhart and Chute, he states the problem, lists the apparatus, and gives full directions for performing the experiments, with a form for tabulation to be used in making a record of the results.


3 Henry S. Carhart and Horatio N. Chute, Physics with Applications. (Chicago: Allyn and Bacon, 1917).
Each of his manuals is brief in discussion of subjects and contains a small number of exercises as compared with some of the later texts.

The topics and problems presented in this manual are as follows:

Chapter I. Introduction

Chapter II. Simple Measurements

1. Measurements of Length, Area, and Volume.

   Problem 1. To measure the length and the breadth of a table . . . , employing English and metric measure.

   Problem 2. To find the ratio of the circumference of a circle to its diameter.

   Problem 3. To find the volume of the metal in a piece of brass tubing.

   Problem 4. To measure the diameter of a wire.

   Problem 5. To measure the diameter of a ball.

   Problem 6. To measure the depth and the diameter of a cylindrical bar, compute its volume, and compare the volume with that obtained by the use of a graduated measure.

   Problem 7. To measure the angle formed by two intersecting straight lines.

   Problem 8. To find the area of a triangle formed by lines drawn on a page of the notebook.

   Problem 9. To find the volume of a small irregular body.

2. Measurement of Mass

   Problem 1. To find the mass of a body.

   Problem 2. To find the weight of a body by means of Jolly's balance.
Chapter III. Mechanics of Solids.

1. Composition of Forces.
   Problem 1. To test the principle applied in compounding two parallel forces.

2. Curvilinear Motion.
   Problem 1. To test the laws of curvilinear motion.

3. Accelerated Motion.
   Problem 1. To test the laws of accelerated motion.

4. The Pendulum.
   Problem 1. To test the laws of the pendulum and find the value of $g$.

5. The Simple Machine.
   Problem 1. To test the law of equilibrium of the lever.
   Problem 2. To test the law of equilibrium for any given combination of pulleys.

Problem 3. To measure the diameter of a small tube, not capillary, but too small to permit the use of the verniered caliper.

Problem 4. To measure the diameter of a capillary tube.

3. Cohesion.
   Problem 1. To measure the tenacity of a wire.
   Problem 2. To ascertain how the size of a drop of a liquid is affected by the cohesion of the liquid, the shape of the surface on which the drop forms, and the rate of drop formation.

Problem 4. To test the laws of capillary action.
Problem 3. To test the law of equilibrium of the wheel and axle.

Problem 4. To test the law of equilibrium of the inclined plane.

Chapter IV. Mechanics of Fluids.

1. Pressure in Fluids.

Problem 1. To measure the pressure at any point within a vessel of water, and compare the pressure in different directions at that point.

Problem 2. To measure the atmospheric pressure.

Problem 3. To measure the vertical distance between the floor of the basement of a building and that of the top story.

2. Pressure on the Bottom of a Vessel.

Problem 1. To prove that the pressure on the bottom of a vessel varies as the depth of the liquid, and is independent of the shape of the vessel.

3. Law of Boyle.

Problem 1. To test Boyle's law for pressure.

4. The Siphon.

Problem 1. To prove that the rate of flow of a liquid from a siphon is proportional to the difference of length of the arms.

5. The Principle of Archimedes.

Problem 1. To find the measure of the buoyant force.

Problem 2. To prove that a floating body displaces its own weight of the supporting liquid.

Problem 1. To find the density of a solid (name solid) heavier than water and insoluble therein.

Problem 2. To find the density of a solid (name solid) lighter than water and insoluble therein.

Problem 3. To find the density of a solid (name solid) insoluble in water by means of Jolly's balance.

Problem 4. To find the density of a solid (name solid) soluble in water.

Problem 5. To find the density of a liquid (name liquid) by means of the specific gravity bottle.

Problem 6. To find the density of a liquid (name liquid) by weighing a solid in it.

Problem 7. To find the density of a liquid (name liquid) by balancing a column of it against a column of water.

Problem 8. To find the density of a liquid (name liquid) with Jolly's balance.

Chapter V. Heat.

1. The Thermometer.

Problem 1. To test the accuracy of the location of the fixed points on the stem of a mercurial thermometer.


Problem 1. To compare the thermal conductivity of several metals.

Problem 2. To compare the thermal conductivity of wood with the grain with that across the grain.
3. Radiation.

Problem 1. To test the accuracy of Newton's law of cooling, the rate at which the temperature of a cooling body falls by radiation is proportional to the excess of its temperature over that of the surrounding medium.

4. Expansion by Heat.

Problem 1. To determine the coefficient of linear expansion of a metallic rod.

Problem 2. To determine the apparent coefficient of cubical expansion of a liquid.

Problem 3. To determine the apparent coefficient of cubical expansion of air, under a constant pressure.

5. Melting and Boiling Points.

Problem 1. To determine the melting-points of such substances as tallow, lard, paraffin, beeswax, etc.

Problem 2. To find the boiling-point of a liquid.

6. Calorimetry.

Problem 1. To determine the water equivalent of a vessel; that is, to find how much water will equal it in capacity for heat.

Problem 2. To determine the specific heat of a solid.

Problem 3. To determine the specific heat of a liquid.

Problem 4. To determine the latent heat of fusion of water.

Problem 5. To determine the latent heat of vaporization of water.
Chapter 6. Magnetism and Electricity.

1. Magnetism.

Problem 1. To study the action between magnetic poles.

Problem 2. To find the position of the poles of a bar magnet.

Problem 3. To compare the action of magnetic force through sheets or plates of various substances.

Problem 4. To compare the strength of the poles of a bar magnet.

Problem 5. To represent by a curve the change in the magnetic strength as you go from the poles of a magnet to its centre.

Problem 6. To map out the magnetic field of a magnet.

2. Static Electricity.

Problem 1. To study the law of electrical action.

Problem 2. To charge an electroscope.

Problem 3. To ascertain the kind of electrification of a charged body.


Problem 1. To show that local action is prevented by amalgamating the zinc.

Problem 2. To ascertain the action of an electric current on a mounted magnetic needle.

Problem 3. Given strips of zinc, lead, iron, copper, tin, and carbin, to construct an electromotive series.

Problem 4. To study the effect of polarization.
Problem 5. To measure the electrical resistance of a coil of wire by the method of substitution.

Problem 6. To measure the electrical resistance of a coil of wire by means of the Wheatstone Bridge.

Problem 7. To measure the resistance of a battery by the method of reduced deflection.

Problem 8. To measure the resistance of a battery by Mance's method.

Problem 9. To compare the resistance of a single cell with that of two cells of the same size and kind when connected in parallel circuit, and also with that of the same cells connected in series.

Problem 10. To test a galvanometer for the law of tangents.

Problem 11. To find the reduction factor of a tangent galvanometer.

Problem 12. To measure the electromotive force of a battery by the method of constant resistance.

Problem 13. To measure the electromotive force of a battery by the Wheatstone method.

Problem 14. To measure the electromotive force of a cell and compare it with that of two cells of the same kind when joined in multiple arc. Also to compare it with that of two when joined in series.

Problem 15. To investigate the behavior toward each other of two conductors carrying electric currents.
Chapter VII. Sound.

1. Re-enforcement of Sound.

Problem 1. To find what lengths of air-columns will re-enforce the sound of a tuning fork.

Problem 2. To find what correction must be made for diameter in the length of a cylindrical resonating air-column.

2. Velocity of Sound.

Problem 1. To determine the velocity of sound in air.

3. Reflection of Sound.

Problem 1. To test the law for reflection of sound waves.

4. Pitch of Sounds.

Problem 1. To find the vibration number of a tuning fork by the method of interference of sounds.

Problem 2. To find the vibration rate of a tuning fork by means of a resonator.

Problem 3. To find the vibration rate of a tuning fork by means of a siren.

5. Laws of vibrating Rods and Strings.

Problem 1. To investigate the laws of the transverse vibration of rods.

Problem 2. To investigate the laws of vibrating strings.

6. Optical Study of Sounds.

Problem 1. To analyze sounds by means of Koenig's manometric flame.
Chapter VIII. Light.

1. Images Through Small Apertures.

Problem 1. To ascertain how images are formed by small apertures, and what conditions govern their size, brightness, and definition.

Problem 2. To ascertain why an image of every object is not seen imprinted on every other object, in accordance with the principle governing the formation of images through small apertures, any point in space being considered as such an aperture.

2. Photometry.

Problem 1. To measure the candle-power of a kerosene lamp by means of a Rumford photometer.

Problem 2. To measure the candle-power of a kerosene lamp by means of a Bunsen photometer.

3. Reflection of Light.

Problem 1. To investigate the law for the reflection of light.

Problem 2. To measure the angle of a glass prism.

4. Mirrors.

Problem 1. To prove that the image of an object in a plane mirror is situated as far behind the mirror as the object is in front.

Problem 2. To measure the focal distance of a concave spherical mirror. First Method.

Problem 3. To measure the focal distance of a concave spherical mirror. Second Method.
Problem 4. To measure the focal distance of convex spherical mirror.

Problem 5. To determine how a concave spherical mirror disposes of pencils of light.

Problem 6. To determine how a convex spherical mirror disposes of pencils of light.

Problem 7. To determine the character of the images of an object given by spherical mirrors.

5. Refraction of Light.

Problem 1. To measure the index of refraction of water.

Problem 2. To measure the index of refraction of glass.

Problem 3. To measure the principal focal distance of convex lens. First Method.

Problem 4. To measure the principal focal distance of convex lens. Second Method.

Problem 5. To measure the principal focal distance of convex lens. Third Method.

Problem 6. To measure the principal focal distance of a concave lens.

Problem 7. To ascertain how a convex lens disposes of a pencil of light.

Problem 8. To ascertain how a concave lens disposes of pencils of light.

Problem 9. To ascertain the character of the images formed by lenses.

Findings. The author of this text has attempted to write a manual to meet the needs of schools that are limited
in equipment. To do this, exercises and topics are chosen that do not require highly specialized apparatus, but where superior apparatus is available, footnotes are given to enrich the course.

It is not intended for the student to follow directions purely mechanically, but introductory paragraphs precede each experiment so the student will be informed as to the apparatus and procedure to be used.

The student is required to write a conclusion which is a definite answer to the question raised in the object of the experiment.

The order in which the divisions of physics are presented in this manual is Mechanics, Sound, Light, Heat, and Electricity. The author thinks that this order lends itself best to the student's power to master the material offered. Special attention has been given not to overload the student with more manipulations and observations than are reasonable.

Laboratory Exercises in Physics, by Fuller and Brownlee, 4 (1913). In order to keep abreast of the times, the authors have introduced many new features into this laboratory manual.

They first express the desire to proportion the exercises, space the various topics in a logical order, and treat them concisely with numerous divided paragraphs with sub-headings

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4 Robert W. Fuller and Raymond B. Brownlee, Laboratory Exercises in Physics. (Boston: Allyn and Bacon, 1913).
in order to aid the pupil in concentrating his mind on the fundamental points.

If it is true that many recent texts in physics have sacrificed scientific and logical presentation in an effort to interest pupils, this manual has leaned far the other way. The eighty-nine experiments are intended to meet the needs of those schools that have the best equipped laboratories at their disposal, as well as the meagerly equipped. They prepare the students to meet the requirements of the college entrance board with particular effort made to adapt the work to the needs of the pupils not preparing for college.

Fundamental Course

Mechanics

Exercise 3. Measurements of Bodies

Object: To find in metric units the volume of a block of wood.

Exercise 4. Volume Measurement of an Irregular Body

Object: To find the volume of a body of irregular shape.

Exercise 5. Density

Object: To determine the density of wood and of metal.

Exercise 8. Relation between Pressure and Depth

Object: To find the relation between the depth of a submerged surface and the pressure upon it.

Exercise 9. Archimedes' Principle
Object: To determine the relation between the loss of weight of a sinking solid and the weight of a liquid displaced by it.

Exercise 10. Law of Flotation

Object: To determine the relation between the weight of a floating body and the weight of a liquid displaced by it.

Exercise 11. Specific Gravity of Solids

Object: To find the specific gravity of various solids.

Exercise 19. The Principle of Moments

Object: When three parallel forces are in equilibrium, to compare (a) the forces in one direction with the force in the opposite direction; (b) the clockwise moments with the counterclockwise moments.

Exercise 23. Parallelogram of Forces

Object: To find the relation between three forces acting on a body at a point, in order that they may be in equilibrium.

Exercise 25. Force at the Center of Gravity of a Body

Object: To find what is the gravitational force acting at the center of gravity of a body.

Exercise 26. The Pendulum

Object: To observe the effect on the number of vibrations of a pendulum in one minute of (a) change in mass, (b) change in amplitude, (c) change in length.

Exercise 27. The Inclined Plane

Object: (a) To compare the work done in raising a load by means of an inclined plane and in raising it vertically; (b) to determine the mechanical advantage from the length and height of the plane.
Sound

Exercise 35. The Wave Length of a Sound
Object: To determine, at the temperature of the room, the length of sound wave from a C tuning fork (256 V. P. S.)

Light

Exercise 37. Measurement of Candle Power
Object: To determine the candle power of a lamp by means of a Jolly or a Bunsen photometer.

Exercise 38. Law of Reflection of Light
Object: To compare an object with its image in a plane mirror with respect to size, distance, and form.

Exercise 42. Reflection through a Glass Plate
Object: To study the refraction of a ray of light through a thick, rectangular glass plate.

Exercise 43. Refraction through a Prism
Object: To study the refraction of a ray of light passing through a triangular glass prism.

Exercise 46A. Study of a Converging Lens
Object: To locate the principal focus of a converging lens and to study the images formed by such a lens, when the lens is at different distances from the object.

Exercise 47. Conjugate Foci of a Converging Lens
Object: To determine the conjugate foci of a converging lens and their relation to the principal focus.

Heat

Exercise 51. Fixed Points of a Thermometer
Object: To test the boiling and the freezing points on a mercury thermometer.
Exercise 58. Specific Heat of a Metal
Object: To find the specific heat of lead by the method of mixtures.

Exercise 59. Cooling through Change of State
Object: To observe the heat changes taking place during the solidification of acetamid.

Exercise 61. Heat Changes during Solution and Evaporation
Object: To observe the heat changes which accompany solution and evaporation.

Exercise 62. Heat of Fusion of Ice
Object: To find the number of calories of heat required to change one gram of ice to water without warming the ice water above the melting point of the ice.

Magnetism and Electricity

Exercise 66. Magnetic Lines of Force
Object: To find the direction of the lines of force in certain magnetic fields.

Exercise 68. The Simple Cell
Object: To study the chemical and electrical action in a simple voltaic cell.

Exercise 69. The Two Fluid Cell
Object: To study the prevention of polarization in the Daniell cell.

Exercise 70. Electroplating
Object: To electroplate (a) with copper (b) with nickel.

Exercise 80. Study of an Incandescent Lamp
Object: To measure the current, voltage, resistance, and power consumption of an incandescent lamp.
Exercise 81. Lines of Force around a Conductor
Object: To investigate the magnetic field surrounding a conductor.

Exercise 82. The Electromagnet
Object: To study the construction of the electromagnet, and to determine the conditions of its operation.

Exercise 83. The Electric Bell
Object: To study the construction and operation of the electric bell.

Exercise 84. Telegraph Instruments
Object: To study the construction and operation of the instruments used on a telegraph line.

Exercise 85. Operation of an Electric Motor
Object: (a) To observe the effect of a magnetic field on a current-bearing conductor; (b) to study the construction and operation of an electric motor.

Exercise 89. Induced Currents
Object: To cause induced currents to flow through a coil of wire and to determine the laws of such currents.

Additional exercises are suggested for those students whose ability enables them to do a maximum amount of work.

Physics Guide and Laboratory Exercises, by V. D. Henderson, Lyons, and Carnahan. This guide is more of a work book than just a guide in laboratory work. In the minds of some authors, this type of manual robs the student

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of initiative constructive work and discoveries that are intended.

The work in this manual is arranged for three class exercises and two laboratory exercises per week. It is divided into three study-level plans as A, B, and C. The A level deals with those concepts which every student must know to have the most elementary knowledge of the subject. The B group plus the A group are for those students who have a special interest in the subject, and especially those students who are preparing for college. The C level is intended for the superior students who have special aptitude for the subject.

This manual follows the unit plan of organization and may be used with any standard text, or reference guides that may be supplied by the teacher.

Unit I. Mechanics of Liquids

A. What Liquids Are and How They are Affected by Gravity

B. What Liquids Do

C. How to Determine the Specific Gravity and Density of Materials

Unit II. Mechanics of Gases

A. How the Atmosphere is Affected by Gravity

B. How the Volume and Pressure of an Enclosed Gas are Related

C. What Air Pressure Does
Unit III. Molecular Mechanics
A. How Molecular Forces Affect Gases
B. How Molecular Forces Affect Liquids
C. How Molecular Forces Affect Solids

Unit IV. Mechanics of Solids
A. Ways in Which the Motion of Solids Is Affected by Forces
B. How the Motion of Solids is Affected by Forces
C. How Solids Are Affected by Convergent and Parallel Forces
D. How Solids Are Affected by Forces Uniform in Magnitude but Variable in Direction
E. How Solids Are Affected by a Continuous Force Variable in Both Direction and Magnitude
F. What is Meant by Work, Power, and Energy
G. How Solids Are Kept in Equilibrium
H. How Work Is Done by Machines

Unit V. Heat
A. What Heat Is
B. How Heat Is Measured
C. What Heat Does
D. How Heat Changes Matter
E. How Heat Is Transmitted
F. How Heat Is Used in Everyday Life
G. How Heat Does Work

Unit VI. Magnetism and Electricity
A. What Magnetism Is and What It Does
B. What Static Electricity Is and What It Does
C. How Electric Currents Are Generated by Chemical Action
Findings. This manual attempts to guide the student in his study of physics. It begins each unit by giving an overview of what is to follow so the student will have an
intelligent conception of the unit as a whole before he takes up each step in the procedure.

The author recognizes individual differences in the students, so he provides three different levels of work exercise. The classroom and laboratory work is unified. The curiosity of the student is aroused because the work relates to everyday life.

A definite review outline is provided at the end of each unit. This will aid the pupil to better prepare himself for any type of test presented by the teacher or school.

III. ESSENTIAL EQUIPMENT NEEDED

If the physics laboratory is to serve its fullest purpose, there must be enough equipment to meet the needs of the largest class anticipated. No student can be kept interested if he is to spend a large part of his time waiting for someone else to do his work, or get out of his way so he can work.

If the equipment of the smaller high schools, and of some large schools, were examined it would be found that there is a lamentable lack of suitable apparatus and equipment for demonstrations in physics. Many pieces of the older apparatus are merely toys, and these are often out of repair and do not work. Then too, the apparatus is
often so flimsy that even when it is in repair it needs many apologies from the teacher. The apparatus is often so small that the pupils in the back seats do not see what is really happening. We should try to get the apparatus makers and dealers to give us better, bigger, and simpler demonstration apparatus.

This crying need for better demonstration demands, first of all, a campaign of cleaning up and repairing whatever apparatus we now have that is still good and scrapping the rest. 6

In order to have good demonstrations, every physics laboratory should have an instructor's demonstration table. This table should be equipped with some sort of heat, electricity, and running water. The table should be raised so that the demonstrations can be seen from all parts of the room. The rear of the table should have ample cupboard and drawer space.

The State Department of Public Instruction has recommended a list of the amount of individual apparatus in physics. Charles W. Wefer in his thesis, "A Study of High School Physics in Porter County, with Special Emphasis on Storage Facilities and Waste in Apparatus," gives a complete list of the amount of individual apparatus recommended by the state. In this same study of nine schools in Porter

County, he found that the lowest school had 33 per cent of the required equipment on hand and the highest school averaged 300 per cent. This shows that some of the laboratories are very poorly provided with sufficient individual equipment, and most of the work has to be done at the teacher's desk or demonstration table. He also points out that five of the nine schools studied have no demonstration tables, and that the percentage ran much lower for demonstration apparatus than for individual apparatus. Of course, this is for only one county in the state, but most of our high schools, as a rule, have about the same amount of equipment.

This study further shows that it is possible to supplement some equipment by home-made materials. There is a trend, on the part of the school administrators, away from a separate laboratory for a specialized subject, to a laboratory equipped for general work in science.\(^7\)

IV. SUGGESTION FOR MAKING PHYSICS MORE ATTRACTIVE

It has been suggested that home-made equipment may be used to increase the laboratory storeroom supply. Mr. Eldred R. Harrington showed how he reconditioned motors obtained

from junk. The manual arts department was enlisted in making such articles as could be made in that department. Transformers were used in the place of the old inefficient dry batteries that had to be replaced each season. Interested citizens donated parts of radios to interest the students in building a set for their own use. The printing department printed the experiments, thus adding interest to the course to such an extent that this author reports a 300 per cent increase in enrollment after this plan was inaugurated.

Mr. J. W. Moelk in his article states that aside from the usual book reports, talks, and extra-credit papers, he has added a display case for model toys and apparatus illustrating physical principles that attract the attention of a large number of students who otherwise might never come in contact with the physical phenomena shown. A list of his display includes: a heating coil placed about two feet from the radiometer and connected electrically so that it can be operated by a switch, an electric whirl, student made steam engines, motors, electroscopes, hygrometers, radio tubes,

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8 Eldred Harrington, "How to Increase the Laboratory Equipment," School Science and Mathematics. (January, 1936)

Geissler tube, working demonstration of a bi-metallic thermostat, maps of magnetic fields, model aeroplane exhibit, cathode tube demonstration, and the operation of an automobile engine, made by means of an electric motor. This was not all that was used during the year, but it did much to add interest to the physics work and prompt the making of home-made equipment.

Dr. Alfred W. Hurd\(^\text{10}\) suggested three reasons for the need of reorganization in the teaching of physics as:

1. Discoveries in physical science are rapidly changing the content of physics.
2. The development of individuals.
3. The school population is different from that of a few years ago, for those pupils who cared to attend high school then did so; now, on account of compulsory educational laws and propaganda many more attend school.

This changes the problem of instruction and makes it necessary to provide an interesting course which will attract the attention of a tremendous variety of tastes. Dr. Hurd thinks much more can be done by doing fewer experiments and having more classroom demonstration where the students look on and follows with his mind and eyes.

CHAPTER VI

GENERAL SUMMARY AND CONCLUSIONS

I. CONCLUSIONS

We, as teachers of physics, must do something about our teaching. We cannot afford to stop studying modern physics for that is the great incentive that keeps this science new. Some new topics are to be added each year, causing us to place less emphasis upon the old topics.

We must convince the students that physics is a practical, growing science, and that there is much to be done in its development. Many students retain very little information relative to science after they leave school. One reason for this is that the subject matter does not relate to everyday life, and it is soon forgotten.

A remedy for the inadequacies in the teaching of high school physics may come under the following suggestions:

1. Set up definite aims and objectives.

2. Subject matter must be suited to the needs of the pupils.

3. Teachers of science must be trained for the practical presentation of physics.

4. Students must be given greater responsibility and freedom of action, with motivation.
5. Future changes in the course must be anticipated and research encouraged.

Science teaching must be redirected because science is largely responsible for the production of coordinated units of new knowledge, which when unguided must do harm instead of good.

This is now the age of practical science, and it must be freed from tradition, prejudice, and superstition which will hamper its development. Its growth depends upon the early use of research by beginning students.

II. RECOMMENDATIONS

According to the state course of study there must be a definite number of minutes spent each week in the teaching of any laboratory science. This time may be divided into class conferences, class demonstration, and laboratory periods. Some teachers find it very desirable to have only one hour each day for laboratory work, while others prefer forty minute classes three days a week and two forty minute laboratory periods two days a week.

Both of these methods of dividing the work have their merits. The use of single period as discussed by Clyde Krenerick\(^1\) has some decided advantages. It makes it possible to keep a perfect correlation between the laboratory

work and the classroom discussion. In this article, he
states that the tomorrow's task is seldom discussed in class.
Each student is required to get his own lesson and do his
own work, for, otherwise, he would be robbed of that certain
thrill, or pride, that goes with having done a difficult job
well.

The set-up of the laboratory work is such that only
a few of the better students succeed with all the experi­
ments, thus taking care of the superior student as well as
the average. This is hard on a few of the students. How­
ever, with our enforced mass education, we can not provide
special methods for each student, but must use the method
that gives the greatest good to all concerned.

One method of conducting a laboratory period is sug­
gested by Clyde Krenerick as follows:

On laboratory days the students at once pass
from the recitation room to the laboratory. They
are not allowed to consult the textbook in the
laboratory, and they do not communicate. They have
been instructed, and soon learn from experience,
that they must make previous preparation. The
instructions or directions for the experiments are
intentionally so written that the student must have
a knowledge of certain fundamental facts given in
the previous day's assignment. If he has not such
knowledge, he is soon lost, and it is very evident.
He knows that he is graded for each day's accom­
plishment and so a failure here is like a failure
in a written test.\(^2\)

This method it seems, would require the students to
know definitely what they are going to do and how to do it

\(^2\)Ibid., p. 516
before they come to the laboratory. Too many of our present
day laboratory manuals are of the receipt book order. The
experiments are mapped out, move by move, until all the
student has to do is hold the book by his side and follow
directions specifically. This robs the student of any
initiative he may have to find the thing out for himself.

For the recording of the work, a notebook is kept.
It is described in the article by Clyde Krenerick as follows:

For the laboratory record we use a bound hard­
covered notebook. The manual gives a tabulation
form for the record of each experiment. The students copy
this tabulation on a left-hand page in their notebooks
before coming to the laboratory. They are required to
record their readings or data directly in the notebook
in ink. If a mistake is made it is not considered a
sin. Brackets are placed around the part that is wrong
and it is rewritten below. This may not make the most
beautiful notebook, but we prefer that it be a work book
rather than a state-fair exhibit.

Some of the items in the tabulation are the results
of computation. The indicated steps of this computation
are recorded on the same line on the right-hand page.
This aids greatly in checking the results and the methods
of computation. The answers to questions or the con­
cclusions called for in the manual are written underneath
the tabulation. These statements are usually lettered
so that the instructor knows exactly where to look for
what he wishes to find. When the student has finished
his record he takes it immediately to the instructor for
checking and grading.

Under the provisions of this type of laboratory, no
chance is given the student to borrow work as it must all be
completed in the laboratory. If the work is not complete,
the student may do it outside, but very little credit, if
any, is given for this work. This prompts the student to
come prepared and not waste his time while in the laboratory.

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Ibid., p. 518
The double period twice a week laboratory method may be carried out much the same as that suggested under the one period method, but there are a few advantages that should not be overlooked.

In the smaller high schools, we find that it is necessary to share the laboratory with some of the other sciences, such as biology and general science. In this case, it would be wise to divide the use of the laboratory in such a way as to accommodate the other classes. For instance, let the physics class use the laboratory Monday and Tuesday, biology Wednesday and Thursday, with the general science coming on Friday.

The class work and demonstration could be made to precede the laboratory work, and a closer supervised course would make the use of the laboratory less essential.

The success in teaching physics does not depend upon the method used so much as it does upon the ability of the teacher to make any system work. The things desired are interest on the part of the student in the subject, and the amount of real work they are willing to give to the mastery of the subject. Students as a rule like to do something for themselves. The laboratory gives them an opportunity to do definite problems individually, and, as a result, the learning is made easy.

The laboratory can be made the hub around which the entire course is built. The best and most effective way to learn is by doing.
The author also wishes to recommend the use of weighted test questions, such as those shown in the appendix. These tests may be made by the science teacher or purchased from the book companies.

A few of the advantages to be had from the use of such a test are as follows:

1. The problem may be given more weight in grading than short easy questions.
2. An easier method of evaluating the different answers is provided.
3. The teacher's personal feeling is eliminated.
4. Students may see for themselves the relative value of each question.
5. The tests are prepared on mimeograph forms so that the teacher is relieved of a certain amount of last minute drudgery.

The author wishes to report the use of weighted questions through the year's (1935-36) work in physics in Lincoln Township High School, LaPorte County, Indiana, with pleasing results.

The questions were prepared by a publishing company and submitted for use in connection with its adopted text. The science teachers selected those questions which suited the needs of the class, prepared them in mimeograph form, and on a pre-announced date submitted the questions as a unit test.
The papers were marked according to the weight given to each problem or question. The grades were direct indications as to how difficult a problem each student was capable of solving.

The students found the tests just, fair, and not composed of unnecessarily difficult problems. On the whole, the students performed better and with better spirit on a test of this nature than they did on the essay type, or any other type previously presented.

The justification for giving such tests may be found in Tests and Measurements in High School Instruction by Ruch and Stoddard. A booklet of twenty-six tests by C. R. Glenn and E. E. Obourn, covers mechanics, heat, electricity, sound and light. Such tests provide rich source material in the preparation of objective examinations, and for instructing the students who are reviewing for the more difficult examinations prepared by Dr. J. F. Mackell and distributed through Purdue University.

III. GENERAL SUMMARY

In making this study the author set up the problem of placing the teaching of physics on an economic, scientific, and usable basis. To do this, there must be uniformity and

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4 G. M. Ruch and George D. Stoddard, Tests and Measurements in High School Instruction.

standardization. Many trends in the teaching of physics have been noted in an effort to point out some of the things that are being done, and what should be done to better meet the needs of such a growing subject.

**Trends.** This study reveals a number of trends which are the results of the popular demand and new discoveries. The text books of the later periods emphasize some topics in physics, and other topics are eliminated. These units are referred to as they relate to the discussion of modern appliances.

The State Department of Public Instruction has made regulations for the use of texts, fixed courses of study, and designated standardized tests to be used by all the secondary high schools. This tends to standardize the time spent in laboratory work, class discussion, and class demonstration. As a result, direct comparison can be made, one school with another, which tends to foster improvement in available equipment and general student participation.

There is a tendency to discontinue the use of the double period laboratory method and use in its place the single period laboratory method, supplemented with class discussion and class demonstration. This is being done with the intention of saving space and time in the laboratory. The laboratory is to be used for work of a general nature, such as: biology, general science, and physical geography.
Physics in the past has been too exacting for the average student. The increase in high school enrollment has caused an effort to be made to present a course in physics that will be more attractive and meet the desires of the varied types of students.

The science teachers have made a definite effort to measure the progress of the students more objectively. To do this, they have resorted to the use of standardized new-type tests which assist the student in unifying his knowledge of the course.

The laboratory guides have become more of a work book than a physics manual. The reason for this development is an effort to lift a load off the teacher and increase the sale of already prepared material. This has been a hinderance to the development of laboratory work, because too much work is done for the student. He becomes lazy and disinterested in his physics experiments.

Where we find one extreme, we sometimes find it followed by another extreme. Laboratories were equipped with high priced equipment. Now, we find the laboratory cluttered with a great amount of home-made equipment, designed to perform one experiment. This may be a good trend, but an alert teacher would not let this be overdone. It is possible to have a few commercial machines designed to take care of as many as one hundred different profitable experiments. These machines may be purchased for a reasonable price.
With the increase in high school enrollment, the teachers recognize individual differences in ability and dominant interests of the student to a greater degree. The student may choose a program that suits his likes and thus increase his chances of success. With this comes a demand for specially trained science teachers. Their training has adopted definite methods of presenting the subject so that it will emphasize practical applications necessary to popularize the course in physics.

We see in the study of texts representing the various periods, a decided change in material and methods. This may be called the new and the old physics. The physics that is new today must be old tomorrow. Only a few things will remain constant, such as the vocabulary and certain fundamental principles. We can not hope to place all the emphases on making old material attractive when so much that is new comes to us.

In this study of old and new textbooks it is evident that elementary physics courses are rapidly expanding. Some units are receiving much more emphases than others until a few once important topics have all but disappeared from the new texts. The latest effort to produce new textbooks have made them too comprehensive; for the authors have tried to include the old and much of the new. This makes the books too bulky.
In the teacher's effort to present all the material to the students he becomes confused and jumps from one topic to another. There is no unity, no connecting link and insufficient time for the material to be applied to life problems and digested. The student is expected to take too much for granted and not enough time is given to experimental physics. This makes teaching harder, study on the part of the student less desirable, and the inductive spirit of solving nature's problems is lost.
CHAPTER VII

BIBLIOGRAPHY

I. BOOKS


Cole, George C., Chairman of Division of Elementary and Secondary School Inspection, State Course of Study in Physics for Indiana. Indianapolis: Indiana State Department of Public Instruction, 1933. Bulletin Number 100 E.


Fuller, Robert W., and Brownlee, Raymond B., Laboratory Exercises in Physics. Boston: Allyn and Bacon, 1913.


Ruch, S. M. and Stoddard, George D., *Tests and Measurements in High School Instruction*.


II. PERIODICAL ARTICLES


APPENDIX
The questions have been worded so, "yes" always shows the desirable performance with, "no" as its absence.

I Aims or Objectives
   A. To better understand the progress of the student with respect to the group.
   B. To keep the work in line with the work required by the State Department of Public Instruction.
   C. To improve the teacher in relating the science of Physics to the students every day life.

II Class Conference
   A. Teacher Activities
      1. Do the assignments in Physics stimulate pupils to recognize new problems and try to search for the solutions?
      2. Does the class conference relate directly to the Physics demonstrations?
      3. Do the students accept a few necessary dry scientific facts?
      4. Does the conference center around questions and answers of the science students?
5. Does the teacher consider the dominant interest of the students in conference discussions?

6. Does the teacher recognize individual differences when asking for additional experiments?

7. Does the teacher recall the previous days work before taking up new material?

B. Student Activity

1. Does the class conference add to the pupils knowledge of science so he is more efficient socially?

2. Does the student show initiative, desire to learn and intellectual, scientific curiosity?

3. Does the student take pride and joy from doing his work in science?

4. Does the student always work to his ability without undertaking the discouragingly hard mathematical calculations?

5. Does the student give the same attention to class discussion as to physics demonstrations?

6. Does the student show a reasonable amount of courage when confronted with a difficult science problem?

III Class Demonstration

A. Teacher Activities
1. Does the teacher choose physics equipment large enough to be seen from the farthest corner of the room?

2. Is the apparatus logically placed so the teacher and student is at ease while the demonstration proceeds from one step to the next?

3. Does the physics teacher use positive effects (motion) in preference to negative (rest)?

4. Does the technic and clearness of the demonstration stimulate better laboratory work by the pupils?

5. Is the mentality and development of the entire class ready for the experiments selected?

6. Does the demonstrations seek to develop attention and motivation as well as lasting scientific impressions?

7. Does the teacher make full use of visual aids in the teaching of physics?

B. Pupil Activity

1. Are the experiments classified so the finely marked instruments (micrometer) may be studied by the student and they may have a chance to examine the apparatus?
2. Do the problems demonstrated leave the student with anything to discover for himself?

3. Are the students given an opportunity to prepare a demonstration for the class?

4. Do the students evaluate and criticize constructively during student presentation?

5. Do the students bring in questions relating to the demonstration from outside sources as questions from science magazines?

6. Does the student keep an up-to-date note book of the demonstration as well as a record of laboratory work?

IV Laboratory

A. Equipment

1. Do other teachers use the physic laboratory for class use?

2. Is the physics apparatus in units readily accessible to the pupils?

3. Are work-benches and tools for repairing physics apparatus available in the building?

4. Is there a definite place for every piece of apparatus?

5. Does the teacher provide a place for safe keeping of valuable electrical instruments?
B. Teacher Activities

1. Does the teacher give the great scientist credit for their contributions?
2. Does the teacher encourage the pupil to assist in the demonstration?
3. Does the teacher introduce sufficient problems to produce effective use of the apparatus?
4. Does the physics laboratory period provide for sixty to ninety minutes in length?
5. Does the teacher waste material and carelessly use and misplace physics apparatus?
6. Does the science teacher use the single or double period?
7. Does the teacher increase laboratory equipment through the use of the school shop?
8. Does the teacher have the pupil do enough demonstration to prove the principle?
9. Does the teacher develop habits of scientific investigations in the pupil?
10. Does the physics laboratory lesson draw conclusion and make application?

C. Pupil Activities

1. Does the pupil know clearly his method of procedure?
2. Does the pupil have a physics laboratory manual?

3. Does the pupil improve in his physics demonstrations?

4. Does the physics demonstration prove to be worthwhile?

5. Do pupils need to do more physics demonstrations to prove the principles studied?

6. Do pupils carry on conversation about the science work at hand?

7. Do the pupils develop habits of careful observation, accurate measurement, and orderly arrangement of the scientific information they acquire?

8. Do pupils keep hands off of all physics apparatus until instructed in its use?

9. Do pupils put physics apparatus in designated place after use?

V. Notebook

A. Does the teacher require the following record of the physics experiment?

1. The problem?

2. The apparatus?

3. The drawing?

4. The method?
5. The results?
6. The questions?

B. Does the teacher require that the original data of the experiment be recorded as the physics experiment is in the process of being worked?

C. Does the teacher require the students to keep class notes in physics notebooks?

D. Does the teacher use the notebook as future physics class reference?

E. Does the teacher grade the physics notebooks on basis of:
   1. Heatness?
   2. Exactness?
   3. Thoroughness?

F. Does the teacher use prepared physics notebooks with blank spaces to be filled in by the pupils?

G. Does the teacher require pupils to write their physics notebooks in ink?

H. Does the teacher keep notebooks in the science laboratory?

I. Does the teacher mark physics notebooks in the presence of pupils?

J. Does the teacher require pupils to write reports of field trips in their physics notebooks?
K. Does the teacher make the notebook a valuable aid in teaching and learning physics?

L. Does the pupils' conclusion show evidence that he knows the purpose of the physics experiment?

M. Are the records of the physics experiments kept in the laboratory until the experiment is completed?

N. Are the notebooks used for recording physics laboratory work and other assignments?

VI Supplementary Material

A. Does the teacher file science magazine articles?

B. Does the pupil have access to such file?

C. Does the pupil give special physics reports?

D. Is the laboratory well supplied with physics reference material?

E. Do the pupils use this reference?

F. Does the teacher allow the pupils to investigate some phase of physics for themselves?

G. Are the pupils allowed to work out supplementary physics experiments?

H. Does the teacher furnish free science literature for the pupils?

VII Field Trips

A. Does the teacher have a definite aim for each trip taken by the physics class?
B. Does the physics teacher prepare the pupils for each trip before the trip is taken?

C. Does the physics teacher or a guide give explanations and answer questions while conducting the trip?

D. Does the teacher supplement the trip with a follow-up discussion of the trip?

E. Does the teacher arrange the trip to coordinate with the physics work being studied?

F. Does the physics teacher consider the age and ability of the different pupils in deciding what to show on a trip?
WEIGHTED QUESTIONS IN SECONDARY PHYSICS

Mechanics and Gases

Directions: Complete each of the following statements by writing the proper word or letter in the space provided in the right-hand margin.

1. The atmosphere is composed mainly of oxygen and nitrogen in the ratio of one part 0 and _______ parts N.  

2. The nitrogen in the air is the (a) supporter of combustion (b) inactive element (c) active element

3. At sea level and at 0° C the weight of 1 cm³ of air is ________ g

4. The weight of 1 cu. ft. of air is______

5. The barometer was invented by ________

6. As one ascends a mountain side, the barometric pressure (a) increases (b) remains the same (c) falls

7. The Magdeburg hemisphere experiment was performed by (a) Torricelli (b) Von Guricks (c) Galileo

8. A pressure of one atmosphere is equal to ________ g per cm³

9. A pressure of one atmosphere is equivalent to ________ lb. per sq. in.

10. A pressure of one atmosphere is equivalent to ________ cm of mercury

11. A pressure of one atmosphere is equivalent to ________ in. of mercury

12. An aneroid barometer contains (a) mercury (b) springs and levers (c) hydrogen

Score

1. ________ (2)
2. ________ (2)
3. ________ (2)
4. ________ (2)
5. ________ (2)
6. ________ (2)
7. ________ (2)
8. ________ (2)
9. ________ (2)
10. ________ (2)
11. ________ (2)
12. ________ (2)
13. A self recording aneroid barometer is called a

14. At places near sea level, as one goes upward, a barometric fall of 0.1 in. indicates an ascent of about _______ ft.

15. When the velocity of a fluid stream increases at a given point, as water issuing from the nozzle of a hose, the pressure at this point (a) increases (b) decreases (c) remains unchanged

16. When a pitched ball is caused to rotate, the pressure on the side toward which the ball rotates is (a) greater than (b) less than (c) the same as on the other side

17. When the volume of an enclosed gas is decreased, the pressure is ________

18. When the volume is decreased, the density of the gas is ________

19. Pressure X volume (pv) equals a constant (c). This is the equational form of _________ law

20. When the pressure on an enclosed gas is 20 lb. per sq. in., the volume is 15 cu. ft. When the pressure is increased to 30 lb. per sq. in., ________ the volume is cu. ft.

21. A common air pump has (a) one valve (b) two valves (c) no valves

22. A jet air pump has (a) one valve (b) two valves (c) no valves

23. A mercury vapor air pump is (a) the most effective (b) a fairly effective (c) the least effective, type of air pump

24. When a stream of air (the wind) blows across the open end of a chimney (a) an upward draft (b) a downward draft (c) no draft is created

25. Compressed air is used in operating (a) vacuum milking machines (b) carpet sweepers (c) air brakes
26. The valves in a common lift pump open (a) upward (b) downward (c) in opposite direction
27. A common force pump has (a) one valve (b) two valves (c) no valves
28. A siphon is a device for transferring liquids from a given level over an intervening height to (a) a higher level (b) a lower level (c)
29. The flow in a siphon is due to (a) water pressure (b) atmospheric pressure (c) hydrostatic pressure
30. The water in a siphon always flows toward the arm
31. The longer the outer arm the rate of flow.
32. At sea level water can be siphoned over a height of ft.
33. At sea level mercury can be siphoned over a height of cm.
34. At a certain place it is found that water can be siphoned over a height of thirty feet. Over what height can brine be siphoned, the specific gravity of the brine being 1.5?
35. In a vacuum a body has (a) the same weight as (b) a greater weight than (c) less weight than, in air.
36. A falling barometer indicates (a) fair weather (b) foul weather (c) unchanged weather conditions.
37. In the northern hemisphere the circulation of air around a low area is (a) clockwise (b) counter-clockwise (c) intermittent
38. Boyle's law holds only when the temperature is (a) changing (b) constant (c) rising
39. According to Boyle's law when the pressure on an enclosed gas is doubled, (a) the volume is doubled, (b) half as great (c) unchanged

SEMESTER EXAMINATION

1. A unit magnetic pole is one that will repel a similar and like pole at a distance of ________ with the force of 1 dyne. 1. (1)

2. Two magnetic poles of like kind, pole strengths 2 and 4 units respectively, are placed 2 cm apart in air. The force of repulsion is ________ dynes. 2. (3)

3. The angle between the north-south direction of a magnetic needle at a given place and a meridian is called the angle of ________. 3. (2)

4. A rod which is negatively charged is brought near a spherical body which becomes charged by induction with positive and negative charges. Which of the induced charges is bound, + or -? 4. (2)

5. When the plates of a condenser are brought nearer together, the electrical capacity of the condenser is (a) increased (b) decreased (c) unchanged. 5. (2)

6. If the size of the electrodes of a Voltaic cell is increased, the e.m.f. is (a) increased (b) decreased (c) unchanged. 6. (2)

7. If 1 g of a given metal is deposited in an electrolytic cell by a current of 1 ampere flowing for two seconds, ________ g will be deposited by a current of 2 amperes. 7. (3)

8. If the number of turns of wire in a solenoid is increased, the polarity of the solenoid is increased, the polarity of the solenoid is (a) increased (b) decreased (c) unchanged. 8. (2)

9. If the temperature of a metallic conductor is increased, its resistance is (a) increased (b) decreased (c) unchanged. 9. (2)
10. The specific resistance of a given wire is 0.000002. The length of the wire is 500 cm and the cross-sectional area is 0.005 cm². The resistance of this wire is ________ ohms.  

11. Two wires having resistances of 3 and 6 ohms respectively are connected in parallel. The resistance when so connected is ________ ohms.  

12. A current of 2 amperes flows between the points A and B in a conductor. The resistance from A to B is 5 ohms. The difference of potential between A and B is ________ volts.  

13. Two wires having resistances of 3 and 6 ohms respectively are connected in parallel between the points A and B. A current divides at A, part passing over each path to B. The current over the wire having a resistance of 3 ohms is 2 amperes. What is the fall of potential over the other wire?  

14. A current of 2 amperes flows through a resistance of 5 ohms for 10 seconds. How many calories of heat are generated?  

15. An electric iron takes a current of 4 amperes under a pressure of 110 volts. The power applied is ________ watts.  

16. A battery is connected to a coil of wire. When the key is closed the current rises slowly because of ________  

17. When a condenser is used in an induction coil, the spark discharged is (a) increased (b) decreased (c) not affected.  

18. When a wire carrying a current is placed in a magnetic field, the field is distorted. The wire always tends to move toward the (a) strongest (b) weakest, part of the field  

19. An electric motor takes a current of 15 amperes under a pressure of 120 volts. This is the input. The motor develops 2 h.p. The efficiency is ________ per cent.
20. Inductance in an a.c. system (a) tends to increase the current (b) tends to decrease the current (c) does not affect the current, strength. 20. ____ (2)

21. A. c. currents are used in transmission lines to prevent (a) voltage loss (b) current loss (c) heat loss. 21. ____ (2)

22. The velocity of sound in air at -25°C is _______ ft. per second. 22. ____ (2)

23. If the volume of an auditorium be increased without changing the absorbing power of the interior, the period of reverberation will be (a) increased (b) decreased (c) unchanged. 23. ____ (2)

24. An open pipe is in resonance with a given fork. The length of the pipe is 4 ft. The wave length of the sound given off by the fork is _______ ft. 24. ____ (3)

25. Quality of sound depends upon (a) the loudness (b) the pitch (c) the number of overtones present. 25. ____ (2)

26. A given string has a frequency of 256 vibrations per second, when the stretching force of 1 lb. What must be the stretching force in order that the string shall sound a note an octave above 256? 26. ____ (3)

27. Intensity of illumination is inversely proportional to the ______ of the distance from the source. 27. ____ (2)

28. A beam of light in passing through a prism is (a) refracted toward the base (b) refracted toward the vertex (c) unchanged. 28. ____ (2)

29. The index of refraction of water is 4/3. This means that the velocity of light in air is ______ times as great as in water. 29. ____ (2)

30. An object is placed between the center of curvature and the principle focus of a concave mirror. The image is (a) erect (b) inverted. 30. ____ (2)

31. The image (item 30) is (a) real (b) virtual. 31. ____ (2)
32. The image (item 30) is (a) larger than (b) smaller than (c) the same size as, the object. 22. (2)

33. A concave lens always gives a (a) real (b) virtual (c) distorted, image. 33. (2)

34. Radio waves to be heard must be (a) modulated (b) damped (c) discontinuous. 34. (2)

35. In a vacuum radio tube the electrons pass (a) away from the filament (b) to the filament (c) back and forth between the filament and the plate. 35. (2)

36. The wave length of cosmic rays is (a) equal to (b) greater than (c) less than, the wave length of X-rays. 36. (2)

37. A radioactive substance (a) loses weight (b) gains weight (c) is unchanged in weight, as time goes on. 37. (2)

The lettered items (a), (b), (c), etc. at the end of this test are important laws in physics. Put the letter of each law in the blank opposite its name.

38. Law of magnetic attraction and repulsion 38. (2)

39. Faraday's first law of electrolysis 39. (2)

40. Lenz's law 40. (2)

41. Ohm's law 41. (2)

42. Joule's law of heating 42. (2)

43. Second law of strings 43. (2)

44. Law of inverse squares 44. (2)

45. Law of sines 45. (2)

(a) To every action there is an equal and opposite reaction.

(b) The current strength is equal to $E/R$.

(c) The mass of a substance deposited is directly proportional to the current and the time which it flows.

(d) Unlike signs attract and like sign repel.

(d) One B. t. u. of heat is equivalent to 778 ft. lb.
(f) When a change occurs in an electromagnetic circuit, that thing happens which tends to oppose the change.

(g) The frequency is directly proportional to the square root of the stretching force.

(h) The heat developed by a current is directly proportional to the square of the current, the resistance, and the time.

(i) Index of refraction is equal to sine \(i\) divided by sine \(r\).

(j) Intensity of illumination is inversely proportional to the square of the distance from the source.