A TECHNIQUE FOR
THE SELECTION OF LABORATORY EXPERIMENTS FOR
A COLLEGE GENERAL EDUCATION PHYSICAL SCIENCE COURSE

A DISSERTATION

SUBMITTED TO THE GRADUATE COUNCIL OF WAYNE STATE UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF EDUCATION
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WITH A SPECIALIZATION IN ADMINISTRATION AND SUPERVISION

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Introduction

In recent years increasing attention has been given to the philosophy of general education. Educational philosophers have been determining objectives and defining goals for general education. Research has been conducted to measure the contributions being made and to evaluate the results being obtained by institutions which have adopted programs of general education.

Science at the college level has been influenced significantly by the movement. Science in general education has expanded rapidly, challenging former "traditional" science-education, particularly as it affects the academic lives of the majority of undergraduates who are identified as non-science students.

As concepts of general education have assumed positions of greater importance in the pilosophy of higher education, as physical facilities have been acquired to accommodate increased enrollments, and as problems in the field of science-education have been identified and studied, the role of the use of laboratory in science courses for general education has received increasingly greater attention.

Statement of The Problem

The purposes of this investigation are (1) to evaluate a laboratory program accompanying a college Physical Science course at Wayne

State University, and (2) to test experimentally a method of selection of laboratory experiments for a Physical Science laboratory program which would provide desirable science-education experiences for the general education of college students.

The basic assumption of this investigation is that the laboratory is an important teaching technique of the science courses. With wider employment of the laboratory in general education science courses, an evaluation of "traditional" experiments seems necessary. A determination of the scientific principles which are illustrated by selected traditional experiments should be made, and some measure of the value of such experiments should be established. Because experiments have been used for many years does not provide sufficient basis for rejecting or retaining them. A legitimate question, however, should be, do these experiments perform the service they have been assumed to perform? If they do, how might they be properly exploited in appropriate general education science courses? If they do not, what information might they provide in guidance to the preparation of more effective experiments?

Review of Relevant Literature

Relevant background science-education research.--In the Second Annual Review of Research in Science Teaching under a sub-heading entitled "Review of Research in Science-Education for the College Level," a comprehensive review was made of the research in science-education which had been completed since World War II. The following statements which appear in the summary of that review are related to this study:

> It appears from the research studies pertaining to teaching science on the college level that greater emphasis is devoted to the teaching of the biological and physical sciences for general education. . . .

It is suggested that further study be made in the determination of what content and materials be employed in the teaching of science. Many topics appear in textbooks and are therefore used in teaching science with little or no attention given to the criteria for selecting science materials and experiences. What scientific basis, if any, do we have to include many topics or principles in the textbooks?

If the selection of science content and student experiences are dependent upon the objectives of teaching science, then some good studies in this area are needed.[1]

Of particular importance in the research concerning science in general education is Wise's[2] study in which a determination of the importance of 272 principles in the physical sciences of physics, chemistry, and geology was made. Wise's work was a synthesis of four earlier studies by Arnold[3], Robertson[4], Pruitt[5], and Hartmann and Stephens[6].

From the time of Wise's work in 1941 until the present, curricular

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[1]Kenneth E. Anderson, Herbert A. Smith, Nathan S. Washton, and George W. Haupt, "Second Annual Review of Research in Science Teaching," Science Education, 38 (December, 1954), 333.

[2]Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education." Unpublished Doctor's dissertation, University of Michigan, 1941.

[3]Herbert J. Arnold, The Selection, Organization, and Evaluation of Localities Available for the Unspecialized Field Work in Earth Sciences in the New York City Region, Doctor's dissertation. New York: Columbia University, 1936. (Published as a George Peabody College for Teachers Contribution to Education.)

[4]Martin L. Robertson, "The Selection of Science Principles Suitable as Goals of Instruction in Elementary Science," Science Education, 19 (February and April, 1935), 1-4, 65-70.

[5]Clarence Martin Pruitt, An Analysis, Evaluation, and Synthesis of Subject Matter Concepts and Generalizations in Chemistry. Doctor's dissertation, Teachers College, Columbia University, 1935. (Distributed through Science Education.)

[6]George W. Hartmann and Dean T. Stephens, "The Optimal Teaching Sequences for Elementary Physical Principles Based on a Complete Scale of Pleasure-Value and Difficulty of Insight," Journal of Educational Psychology, 18 (September, 1937), 414-436.

research in science-education has expanded progressively to include a variety of studies relating to physical science courses. Blanchet[7], following Wise at the University of Michigan in 1946, devised a basis for the selection of course content for survey courses in the natural sciences, particularly concerned with junior college level courses, by ranking Wise's principles in order of importance to college general education physical science courses.

Surveys of the status of physical science courses, trends in college curriculum evolution, and evaluation of science in general education have not been numerous but have been conducted in varying degrees of extensiveness during the period 1938 to 1955. Watson[8] conducted such a survey of 1239 colleges in 1938-1939. He found that 30 per cent offered the physical science course and that teachers' colleges offered it with 3 times greater frequency than liberal arts colleges or junior colleges.

In Bullington's[9] survey in 1948 of current practices and trends in 720 four-year colleges, he found that 59 per cent offered general education science courses. Thirty-eight per cent of the courses were taught by a single instructor while the other 62 per cent of the courses were conducted by more than one instructor. Forty per cent of the

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[7]Waldo Emerson Blanchet, "A Basis for Selection of Course Content for Survey Courses in the Natural Sciences." Unpublished Doctor's dissertation, University of Michigan, 1946.

[8]Donald R. Watson, "Survey Courses in Physical Sciences, Their Status, Trends, and Evaluation." Unpublished Doctor's dissertation, University of Southern California, 1940.

[9]Robert Adrian Bullington, "A Study of College Science Courses Designed for General Education." Unpublished Doctor's dissertation, Northwestern University, 1949.

instructors were employed specifically for general education courses. Thirty per cent of the instructors devoted full teaching time to the general education science courses. A significant statistic in his study was that 68 per cent or 102 of the 150 general education science courses described had laboratory work of some kind.

Of the survey type of research more recent than Bullington's but more sectional in nature is a study by Wilson[10] in 1951 of the status, content, and practices concerning integrated science courses in Southern Association senior and junior colleges. An interesting statement of status by Wilson is:

> It is clear that general education science courses have not gained widespread recognition in Southern Association Colleges. It is not likely that these courses will be developed widely, especially in junior colleges, unless they gain acceptance as legitimate courses for transfer purposes. The attitude of many of the junior colleges is expressed in a comment from a junior college dean, 'We regard the general science courses as being most worthwhile. . . . However, the main control on course offerings is the transfer quality to senior colleges.'[11]

In this 1951 study Wilson found that general education science courses were being taught in 48 per cent of all Southern Association colleges, with teachers' colleges showing 76 per cent and junior colleges showing 40 per cent. The general survey was the most common course organization for the general education science courses, the "block-and-gap" organization and the historical study were in use relatively little.

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[10]Leland L. Wilson, "General Education Science in Southern Association Junior and Senior Colleges." Unpublished Doctor's dissertation. George Peabody College for Teachers, 1951.

[11]*Ibid.*, p. 33.

In 1952 Rankin[12] conducted a survey concerning problems involving staffing general education science courses. Five significant competencies deemed desirable for instructors as determined by Rankin are briefed as follow:

1. The ability to explain basic facts, concepts, theories, and laws of physical science.

2. The ability to explain science concepts in terms understandable to non-science majors.

3. The ability to devise and use effectively appropriate demonstrations of scientific principles.

4. The ability to relate the various fields of science to each other.

5. The ability to employ techniques and arrange content in a manner to insure student participation.

In summarizing his work he proposed that instructors should have broad training in physical science, accompanied by training in psychology and principles and methods of instructing. Also, he proposed that instructors should specialize additionally in one area other than physical science.

Curriculum studies of physical science courses are generally of two types, viz., analyses of courses of institutions with which the authors were closely associated, or proposed courses based upon a philosophical approach using objectives defined by the author. Such studies by Reynolds[13],

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[12] Oren R. Rankin, "A Study of Competencies for Instructors of College General Education Courses in Physical Science." Unpublished Doctor's dissertation, University of Illinois, 1952.

[13] Charles W. Reynolds, "The Development of Generalized Science Courses in State Teachers Colleges." Unpublished Doctor's dissertation. George Peabody College for Teachers, 1938.

Friedenberg[14], Wilkes[15], Goins[16], Shawver[17], Yale[18], and Cronkite[19], consider curriculum development problems which are deemed important by Anderson, et al, when they state: "One of the basic problems confronting college teachers is the determination of a suitable program of science instruction for general education."[20] Yale's[21] study illustrates the former approach in which he limits his consideration of curriculum development to a specific group of students, non-science majors, at a specific institution, the University of Denver, and in a presently existing course. Conversely, Jordan[22], used the latter approach, as did

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14Edgar Z. Friedenberg, "A Technique for Developing Courses in Physical Science Adapted to the Needs of Students at the Junior College Level." Unpublished Doctor's dissertation, University of Chicago, 1947.

15William T. Wilkes, "Man and His Natural Environment: A Sophomore Science Offering in the General Education Plan of the Troy, Alabama State Teachers College." Unpublished Doctor's dissertation, Columbia University, 1949.

16William Fauntleroy Goins, Jr., "An Evaluation of Science Courses Offered for General Education in Selected Negro Colleges." Unpublished Doctor's dissertation, Ohio State University, 1950.

17Benjamin Shawver, "College Science for General Education: Planning for Teaching of Science in a Liberal Arts College." Unpublished Doctor's dissertation, Columbia University, 1952.

18Francis Jaymon Yale, "A General Education Course in Science for Non-Science Majors at the University of Denver." Science Education, 38 (February, 1954), 37.

19George B. Cronkite, "Science Teaching in State Teachers Colleges of the Northwest." Unpublished Doctor's dissertation, Utah University, 1952.

20Kenneth E. Anderson, op. cit., p. 349.

21Francis Jaymon Yale, op. cit., p. 37.

22Richard H. Jordan, "Science in the General Education of Higher Institutions." Unpublished Doctor's dissertation, Cornell University, 1947.

Shawver[23], in which the problem was considered from a philosophical basis by reviewing the relevant literature in the area of science education and in the history of higher education. Guiding principles for planning a science program were established by both and proposed courses were submitted. Comparison of the proposals of Jordan and Shawver are interesting in that Jordan recommends a comprehensive course built around a nucleus of basic science principles and facts while Shawver recommends a course in science built around problems identified and agreed upon by students and faculty.

Brewer[24], Burmester[25], Bowers[26], Haines[27], and Leader[28], were concerned with evaluation which includes information acquired from testing students, student opinion, and the more general consideration of contribution of the physical science course to the total curriculum of an institution.

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[23]Benjamin Shawver, op. cit., p. 166.

[24]W. Lyle Brewer, "Factors Affecting Student Achievement and Change in a Physical Science Survey Course." Unpublished Doctor's dissertation, Columbia University, 1943.

[25]Mary Alice Burmester, "Construction and Validation of a Test to Measure Some of the Inductive Aspects of Scientific Thinking." Science Education, 37 (March, 1953), 131-140.

[26]Raold W. Bowers, "Effects of Natural Science Courses Upon Harvard College Freshmen." Unpublished Doctor's dissertation, Harvard University, 1952.

[27]Florence C. Haines, "Physical Science in the General Education Program of a State College." Unpublished Doctor's dissertation, Stanford University, 1952.

[28]William Leader, "The Expressed Science Interests of Students at the Conclusion of a College Science Survey Course and Their Relationship to Achievement in the Course." Unpublished Doctor's dissertation. Columbia University, 1952.

Physical science laboratory research.--In the area of methods of teaching science in general education at the college level, research is less extensive. Perlman[29] and Forbes[30] concerned themselves with problems associated with physical science laboratory. Kruglak[31] conducted a study in the use of the laboratory in elementary college physics.

In a 1955 survey conducted by Morrow[32] in which 313 colleges and universities were solicited, he reports on the integrated physical science course as follows:

> The Integrated Physical Science Course. The integrated physical science course may apply toward the science requirement for non-science students in 55 per cent of the institutions included in this study. Replies to the questionnaire indicate that:
>
> 1. The usual extent of the course is two semesters for a total of six semester hours credit. Nearly two-thirds of the institutions allot two semesters and six or more hours to the course.
> 2. The physical science course is the total science requirement for non-science students in 31 per cent of the institutions.
> 3. In 67 per cent of the schools offering integrated physical science courses, the science requirement includes a biological science course as well.
> 4. The percentage of time alloted to topics from the major fields of physical science vary greatly among the schools. The average percentages are approximately: physics, 37 per cent;

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[29] James S. Perlman. "Historical vs. Contemporary Problem Solving Use of the College Physical Science Laboratory Period for General Education." Unpublished Doctor's dissertation, University of Minnesota, 1952.

[30] William C. Forbes. "The Laboratory Experience in Science in General Education." Unpublished Doctor's dissertation, Columbia University, 1949.

[31] Haym Kruglak. "Experimental Outcomes of Laboratory Instruction in Elementary College Physics." Unpublished Doctor's dissertation, University of Minnesota, 1951, Pp. 165.

[32] Elman A. Morrow, "A Physical Science Program for the Non-Science Student," p. 2. Bureau of Educational Research, University of Wyoming, 1955.

chemistry, 27 per cent; astronomy, 16 per cent; geology, 14 per cent; meteorology, 3 per cent; and miscellaneous topics, 3 per cent.

5. The survey type course is used in 56 per cent, and the block-and-gap type course is used in 39 per cent of the colleges.
6. Eighty-three per cent of the respondents who reported block-and-gap courses considered them satisfactory as compared to 64 per cent of the users of the survey type course.
7. The lecture-demonstration-laboratory combination is the principal instructional method used. This combination is considered highly satisfactory by those who use it. The second most popular combination consisted of lectures, demonstrations, and discussions. A third satisfactory combination is limited to lectures and demonstrations. Lectures, when used as the sole instructional method, is considered unsatisfactory. The lecture-laboratory combination received only slight recommendation.
8. In the opinion of the respondents laboratory has a definite place in the physical science course. Eighty-four institutions did not use the laboratory as an instructional method; however, only ten of these respondents considered the method used as being entirely satisfactory.
9. The usual time alloted to laboratory work is two hours per week, although 16 of the institutions allot three or more hours to it while four limit it to one hour per week.
10. An overwhelming majority of the respondents stated that two hours per week would be the correct amount of time to allot to laboratory work.
11. Over 92 per cent of the institutions, in this group, reported standard textbooks as the principal source of instructional material, and over half of them employ locally prepared outlines or manuals as supplementary material. A total of 19 different textbooks were reported. Most of the respondents were satisfied with the text they were using.

Morrow's study presents a current, composite picture of the status of the general education physical science course. Considering the surveys of Watson in 1940, Bullington in 1949, Wilson in 1951 for the Southern Association, and Morrow, most recently, the status of the physical science course is one of importance and the course is obviously receiving more extensive attention by colleges and universities in the United States. Of particular interest to this investigation are the items from 7 through 10 of Morrow's research which indicate the current status of the laboratory program in physical science courses.

The utilization, or rather lack of utilization, of the laboratory in the college physical science course in post-World War II years is reflected in the following statement by Anderson[33]:

> At the end of World War II, many junior colleges, senior colleges, and teachers colleges were faced with the problem of accommodating a greater number of students with little or no acquisition of additional space, facilities, and equipment. As a result, a number of colleges were compelled to offer a non-laboratory science course for general education. This was due partly to the sudden increase in enrollment because of the G.I. Bill and the fact that it was simpler to accommodate larger groups of students in lecture-demonstration courses. Likewise, it was more economical to offer the non-laboratory courses for many institutions.

It is not the mission of this investigation to debate the merits of laboratory in the science course, for it has been assumed that laboratory is an important methodological technique of the science course. Relevant to this comment, however, is Bullington's[34] statement.

> General education science courses have been criticized for the frequent lack of laboratory work. Various studies reveal that laboratory with student participation has been used in from 25 to 41 per cent of survey courses.
>
> Actually there is a wide difference of opinion concerning the value of laboratory exercises for the non-science student. Good arguments have been presented both for and against the use of the laboratory. . . .
>
> Some proponents of the laboratory suggest that methods other than the traditional ones must be developed to make laboratory work a significant experience in the life of the non-science student.

A number of scientific investigations of the use of the laboratory and alternate procedures have been conducted. H. A. Cunningham[35]

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[33]Kenneth E. Anderson, _et al._, _op. cit._, p. 348.

[34]Robert Adrian Bullington, _op. cit._, p. 36.

[35]Harry A. Cunningham, "Lecture-Demonstration Versus Individual Laboratory Method in Science Teaching - A Summary," _Science Education,_ 30 (March, 1946), 70-82.

summarized 37 studies related to the lecture-demonstration versus the individual laboratory method in teaching science. He concluded that the method that is best depends upon the desired objectives.

Extreme positions in opposition to the employment of laboratory have been taken. Based upon the findings of a group of science educators of the Fourth National Conference on Higher Education at Chicago in April, 1949, Cherrington[36] presents the following statement concerning laboratory in general education courses:

> No discussion of natural science teaching would be complete without consideration of the necessity of accompanying laboratory work. The old-line science teacher usually disdains 'courses about science' and insists that in natural science the student can learn only by doing. This dogmatic point of view appears highly questionable when it is recognized that in every community there are cultured individuals who derive much in the way of knowledge, understanding, inspiration, and satisfaction from great literature though they cannot write it, from good music though they cannot play it, from noble works of art though they cannot create them. Laboratory work undoubtedly helps to develop in the students the skills of observation and measurement which he cannot acquire vicariously, but is the acquisition of such skills one of the aims of general education? It would seem that an enormous amount of time and energy are expended with little return in the elementary laboratory each semester where the student performs the same sequence of operations that hundreds of thousands of his predecessors have performed during the past centuries and either obtain the numerical values recorded in the instructor's file of data cards or repeats the measurements until sufficient agreement is obtained. Consequently, it is suggested that in general education courses in the natural sciences the student should not be required to spend two or three hours every week in a laboratory pottering his way through a rigid list of experiments. Instead, lecture demonstrations should be used extensively, and the student should be sent to the laboratory only when a truly significant experiment can be performed.

From Cherrington's extreme non-laboratory viewpoint, statements and positions can be introduced progressively until the extreme

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[36]Ernest H. Cherrington, Jr., "Natural Science and Mathematics in General Education," pp. 71-72. Current Trends in Higher Education: 1949. Washington, D. C.: National Education Association, 1949.

pro-laboratory position is reached. Owen of Antioch College, whose long professional life has been concerned with elementary college physics, considers the laboratory as an essential technique in science teaching. Owen's[37] position is submitted in the following:

> There is no doubt that the laboratory offers an excellent means for illustrating certain general principles, for demonstrating such as those of optics and electricity, for giving practice in the handling of numerical data, and for other purposes for which it is used. But how well does the ordinary laboratory experience contribute to the development of skill in applying the scientific method and of desirable attitudes and habits that should go with it? . . . It is assumed that they are assigned because they are valuable for purposes other than to help the student to practice the scientific method and to develop the scientific attitude. But some experiments should be designed so that the student can use the scientific method without help and which lead to results which he can consider adequate. Such experiments can be set up, but only if they use equipment which is well within the student's ability and deal with phenomena which are not strange to him. . . .
>
> Such experiments as this can help the student develop skill in using the scientific method under circumstances which are nearly enough similar to problems in his own life that he can transfer that skill to his own problems. They can also help develop a scientific attitude; for example, to accept factual evidence even if it does not agree with his original prejudgment.

The status of the utilization of laboratory in general education science courses as presented by Bullington[38] in 1949 indicated that of 128 courses for which information was available, 78 courses used laboratory from 1 to 6 hours per week, with 2 and 3 hours (46 per cent and 24 per cent, respectively) the most common periods. As the lack of laboratory was often the reason for criticism of the early survey-type courses, Bullington's data as of 1949 indicated that 47 per cent of the

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[37] Gwilym E. Owen, "Some Contributions the Physics Laboratory Can Make to General Education," <u>American Journal of Physics</u>, 17 (May, 1949), 270-272.

[38] Robert Adrian Bullington, <u>op. cit.</u>, pp. 156-160.

general education science courses (biological, physical, general, and single subject) had laboratory compared to the 25 to 41 per cent figures for the decade, 1930 A. D. to 1940 A. D. His 1949 figure of 47 per cent was an increase over any previously reported figure.

Of 51 specifically designated "physical science" courses, 30 or 59 per cent had laboratory work. Since 7 of those courses had "museum" type laboratory, only 45 per cent of the physical science courses actually had and used facilities for student participation.

Bullington[39] presented the following statement in explanation of the absence of laboratory work in 55 per cent of the physical science courses:

> There are several reasons for the omission of laboratory work. In some schools there is neither laboratory space nor equipment available. The specialized science courses have first choice of facilities, and often there is nothing left for the newer general education courses. The non-laboratory course is certainly less costly to maintain for it requires less teacher time as well as physical equipment. This has been the determining factor in some schools.
>
> Furthermore, there is a conviction among some teachers of general education science that the laboratory is unnecessary.

In 1952 Perlman's[40] doctoral problem was prefaced by a consideration of the current status of the use of laboratory in physical science courses. He stated that the individual laboratory in actual practice is in decline as compared to the lecture demonstration. This position is neither in agreement with Bullington's data of 1949 nor Morrow's data as of 1955. Perlman's reasons for his statement, however, parallel Bullington's reasons for the slow advance of laboratory included in

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[39]Robert Adrian Bullington, op. cit., p. 165.

[40]James S. Perlman, op. cit., pp. 7-8.

physical science courses. Perlman's reasons are briefed as follow:

1. Pressure for reducing costs in the face of an expanding science enrollment.

2. The economy of time afforded by the use of demonstrations in lieu of laboratory.

3. Dissatisfaction with the same routine of the usual individual laboratory practice.

4. The concept that laboratories in college have primarily technical education values rather than unique general education values and functions.

5. Disappointment in the comparative results shown by individual laboratory methods in various experimental investigations.

Perlman suggests that in order to justify the extra time and expense involved, administrators expect the individual laboratory as a method to show significantly better results than other methods. Additionally he indicates that the reasoning which tends to lead away from the laboratory period is based on several positions, which are briefly presented as follow:

1. It is a question of laboratory versus the demonstration.

2. There is too much use of laboratory and demonstration.

3. There is over-emphasis on status quo practices rather than comparison involving possibly better methods.

4. Results have been based on measurement of outcomes of laboratory or demonstration work in terms primarily of facts and principles without consideration of acquisition of instrumental skills, of problem-solving abilities or of scientific attitudes.

Perlman does indicate, however, that certain governing bases exist for the employment of the demonstration technique as well as for the utilization of individual laboratory. He proposes generally, that demonstrations might well be used for situations involving such factors as:

1. Complicated, difficult, dangerous, or expensive apparatus.
2. Experiments where a relatively large amount of material must be covered in a short time.
3. Longer or more difficult experiments.

Perlman's guiding bases for the employment of laboratory work are those which he deems particularly desirable in situations involving the following:

1. Short, easy exercises.
2. Individual difference outcomes.
3. Easily seen and interpreted results.
4. Development of skills and resourcefulness in handling apparatus.
5. Development in understanding of scientific methodology as in inductive processes.

The use of both individual laboratory and demonstrations would seem to afford greater variety of meaningful science-education experiences as well as a possibility of increased interest and motivation.

Balcziak's[41] work at Minnesota undertook to determine the relative effectiveness of the demonstration method, the combined demonstration, and individual laboratory methods, and the individual laboratory method of conducting a course in physical science designed for general education

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[41] Louis William Balcziak, "The Roll of the Laboratory and the Demonstration in College Physical Science in Achieving the Objectives of General Education." Unpublished Doctor's dissertation, University of Minnesota, 1953.

purposes. He found that significant gains in science information were made under each of the three methods. However, there was no significant difference in means among the several methods in the three outcomes which were measured, viz., science information, scientific attitude, and laboratory performance. Balcziak indicated that the differences between students, if present, were probably of the same order of magnitude as the experimental errors.

In a discussion in which he considers current usage of laboratory in general education science courses, Henshaw[42] of Colgate University considers examples of general education laboratory activities. His positive position, taken in 1954, is an optimistic one and consistent with Morrow's 1955 report. Henshaw is convinced that there are now good general education science courses taught without laboratory, but few would not be improved with the introduction of a limited number of carefully designed laboratory activities. He states that these laboratory activities should contribute most to the common objectives of general education:

1. When they deal with situations for which the student does not know the answer in advance.
2. When they call for as much planning, initiative, and creative thinking as possible on the part of the student, that is, provide him an opportunity to experiment in the true sense of the word.
3. When they are integrated as well as possible with the objectives and subject matter of the course.

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[42]Clement L. Henshaw, "Laboratory Teaching in General Education Courses." American Journal of Physics, 22 (February, 1954), 68-75.

4. When they are carried on in an atmosphere in which curiosity is the motivation, rather than academic penalty.
5. When they are conducted by experienced teachers who are in sympathy with the aims of general education and have a sincere interest in developing mature minds.

Henshaw points out that such ideals are hard to obtain. They require much imagination and planning on the part of the instructor. Many science teachers are enthusiastic about these new approaches to laboratory but feel handicapped by a long conditioning to the traditional point of view. Henshaw feels that the urgent need is not for new manuals or treatises on method, but a multitude of brief, candid reports of projects by individual teachers. The student centered "discovery" concept of laboratory has developed as instructors have tried to avoid the routine and prefunctory aspects of the traditional approach.

As illustrated by Kruglak's work, there is evidence that similar changes are occurring in introductory courses for specialists. Henshaw sees valid reasons for the specialist course and those for general education to differ in both objectives and conduct. He feels that besides the discovery type laboratory, there are other valuable features of general education science courses which the great majority of science specialists do not now experience and that the general education movement in science is making a worthy contribution to the much broader field of college pedagogy.

Summary

The evaluation of the Wayne State University Physical Science laboratory program represents the first part of this study. From the recent literature there is majority agreement that the laboratory experiments must be immediately relevant to the lecture material, and that the experiments must be relatively simple and provide meaningful student experience consistent with the objectives of general education. Is this the case at Wayne State University?

The second part of this investigation intends to test, experimentally, a method of selecting experiments which might be included in a laboratory program to provide desirable science education experiences for the general education of college students. Are "traditional" laboratory experiments of value? What kind of laboratory experiments would provide the desired experiences? By what device can a laboratory experiment be selected, tested, and established as an experiment which will provide the desired student experiences?

Recent research in science-education presents a wide range of opinions concerning the value of laboratory to general education college physical science courses. Some research carries the implication that little difference results from various pedagogical methods and poses an interesting question for professional education relating to the use of the laboratory. The experimental design for the selection of laboratory experiments in this investigation will test to a degree the importance of the role of a laboratory program to a college physical science course.

CHAPTER II

THE EVALUATION OF A LABORATORY PROGRAM

The Problem

The purpose of the first part of this investigation is to evaluate a laboratory program accompanying the first semester college Physical Science course at Wayne State University.

The evaluation of the laboratory program was conducted for both the Fall and Spring semesters of the 1954-1955 school year. A questionnaire technique was employed in which the students who were enrolled in the laboratory course evaluated the laboratory program in terms of how it served their needs.

In structuring the laboratory evaluation investigation two problems were faced, namely, what experiments should be used and what kind of items should the student-evaluation questionnaire contain. Since the first semester lecture course covers selected basic concepts in physics and astronomy, the laboratory experiments were selected as they had direct relation to the topical outline and the semester schedule. Some experiments which had been used previously were retained, although modified and reorganized in most cases; others were discarded and replaced with new experiments which were deemed consistent with the selection criteria.

The criteria which were employed for selection of laboratory experiments for possible inclusion in the Physical Science laboratory course were framed with particular reference to the general education nature of the course. Additionally, consideration was given to the fact that the students would not be science majors, and that the course was oriented in the direction of introducing them to basic concepts of physical science. The selection criteria were as follow:

1. The experiment must illustrate concurrently an important topic or sub-topic of the week's lecture course work.

2. The problem must be oriented in the direction of developing skill in the use of scientific method under circumstances which are nearly enough similar to problems in the student's life that the value of that problem-solving technique is apparent as a procedure which he might employ.

3. The experiment must be a problem to be completed during a one-hour laboratory period, designed to promote understanding of science and give practice in problem-solving by scientific method.

4. The experiment must provide opportunity for maximum student participation in a problem-solving situation.

5. The experiment must be relatively elementary so that all students can do something with it, but it must possess sufficient ramifications to challenge superior students.

6. The equipment and physical facilities required must be simple and economical.

The topical outline for the first semester of the Physical Science lecture course contains 30 broad areas. During a typical semester, considering holidays, examination week, and other interruptions to weekly routine, the course can be scheduled at an average rate of 2 topical areas per week for a period of 15 weeks.

Based on a semester of 15 class weeks, the one-hour laboratory period each week provides time for 15 experiments of laboratory problems. To allow for first-week orientation, pre- and post-testing periods, examination week, and a period for evaluation, 12 experiments were actually prepared, scheduled, and used. The 4 weeks during which the topics, mechanics, heat, electricity, and wave phenomena (sound and light) were studied, were selected as trial weeks for the final experimental purposes (the second part) of this study.

Employing the 6 criteria for the preparation of experiments, each of the 12 experiments was prepared to include appropriate references, a specific statement of the object of the experiment, a listing of the kind and amount of materials to be used, a brief discussion and general background orienting the problem to the lecture topic, a procedural technique, and exercises involving student analysis of the laboratory work. The experiments were prepared during the summer months of 1954 and were reviewed by a physical science specialist with the writer in September, 1954. The experiments which were selected are presented in Table I.

TABLE I

LABORATORY EXPERIMENTS FOR FALL AND SPRING (1954-1955)

Experiment	I.	The Study of the Seasons
Experiment	II.	The Study of the Heavens
Experiment	III.	Measurement and Significant Figures
Experiment	IV.	Mass, Volume, and Density
Experiment	V.	Work and Power
Experiment	VI.	Simple Machines
Experiment	VII.	Pressure and Barometer
Experiment	VIII.	Boyle's Law
Experiment	IX.	Heat: A Problem
Experiment	X.	Weather and Weather Maps
Experiment	XI.	The Electric Battery Cell
Experiment	XII.	Sound: Wavelength and Velocity

This study was begun in 1954 at which time the institution in which the research was conducted was known as Wayne University. On July 1, 1956 it was renamed Wayne State University. Since writing and research of this study extended beyond July 1, 1956, reference to the institution is as Wayne State University throughout the writing.

Background of the Physical Science Laboratory Program

The beginning of the laboratory program.--The laboratory program for the Physical Science course evolved over a period of 3 years (1951-1954) through the progressive efforts of Wayne State University physics department staff members who were directly associated with conducting the lecture part of the course. Dr. Everett R. Phelps, Dr. Vaden W. Miles, and Dr. Bertram Donn worked jointly and individually during that period, preparing and adapting 15 laboratory experiments to the first semester lecture course, Physical Science 10A. Students enrolled in the first semester lecture course or those who had completed the lecture course previously, could elect the laboratory course, Physical Science 11A, on a non-credit basis. The laboratory course together with the lecture course could be used by Liberal Arts College students to fulfill the degree requirement of a laboratory science course for the Liberal Arts degree. Such requirement was not applicable for degree candidates of other colleges who took the lecture course.

The 15 experiments which were used during that period are presented as Table II.

TABLE II

LABORATORY EXPERIMENTS USED PRIOR TO FALL 1954

Experiment	I.	North Circumpolar Constellations
Experiment	II.	Elliptical Orbits
Experiment	III.	Causes of Seasons
Experiment	IV.	Time--Standard and Local
Experiment	V.	Measurement and Significant Figures
Experiment	VI.	Work and Power
Experiment	VII.	Mechanical Advantage and Efficiency of Machines
Experiment	VIII.	Force and Pressure of Fluids Against Surfaces
Experiment	IX.	Density by Archimedes' Principle Method
Experiment	X.	Dew Point and Relative Humidity
Experiment	XI.	Boyle's Law
Experiment	XII.	Weather and Weather Maps
Experiment	XIII.	Static Electricity and Magnetism
Experiment	XIV.	Cost of Electricity
Experiment	XV.	Reflection in a Plane Mirror

In order of usage the experiments in the laboratory course closely paralleled the lecture course. They were constructed using the criterion of simplicity as a guiding element. Each experiment required one hour of student activity in the laboratory and involved a minimum of write-up activity outside of the laboratory. Each experiment was employed to illustrate directly some phase of the material which had been presented in the lecture course that week.

The first evaluation of the laboratory program.--To evaluate the early laboratory program in terms of the students who took the laboratory course during the 1952-1953 school year, a student questionnaire concerning the course was employed by the faculty member[1] conducting the laboratory at that time. Seventeen students who were enrolled in 2 sections of the laboratory course answered the questionnaire. When the

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[1]Everett R. Phelps. Records and unpublished data (1953) of Physical Science classes, Wayne State University.

questionnaires were analyzed, evaluative information was acquired concerning the course. Evidence appearing in the completed questionnaires suggested that the laboratory course was helpful to the students in understanding the lecture topics to which the experiments applied.

From these data and discussions with the Physical Science staff the writer planned the evaluation of the current laboratory program using the revised experiments.

The Evaluation of the 1954-1955 Laboratory Program

The preparation of the student questionnaire.--During the Fall (1954) semester and the Spring (1955) semester, the writer assumed the responsibilities as laboratory instructor for 2 sections of students each term, enrolled in the Physical Science laboratory course 193. The Physical Science lecture and laboratory courses were renumbered in 1954. Physical Science 10A and 10B (the lecture courses) were changed to Physical Science 191 and 192, and Physical Science 11A and 11B (the laboratory courses) were changed to Physical Science 193 and 194. Employing the list of 12 experiments, the 2 sections of students of each semester participated in the laboratory program and evaluated it at the end of each semester. The sections of both semesters ranked the same experiments except in the Spring (1955) semester a substitution for Experiment 9, "Heat: A Problem," was made in each section for the experimental purposes of the second part of the study.

The student questionnaire, which was employed, was prepared in 4 sections:

1. Student ranking or relative merit of each experiment in terms of its interest, general education contribution, and helpfulness.

2. Evaluation of the degree to which the laboratory program served the purposes of the students.

3. Evaluation of physical aspects of the laboratory.

4. General evaluation of the Physical Science course.

A total of 50 responses were required to complete the form. The questionnaire, entitled "Evaluation Sheet for Physical Science 193" is included as Appendix A. The administration of the questionnaire was effected at the end of both semesters for all the laboratory sections. Students submitted unsigned questionnaires in an effort to obtain anonymity.

Analysis of the student evaluation data.--From student responses which were submitted in the questionnaire, the evaluation data for the Fall (1954) and Spring (1955) semesters were acquired. These data are presented as Table III.

TABLE III

INTEREST--GENERAL EDUCATION CONTRIBUTION--HELPFULNESS RANKS OF LABORATORY EXPERIMENTS FOR TWO SEMESTERS, FALL, 1954 AND SPRING, 1955

Name of Experiment	Fall, 1954			Spring, 1955		
	A*	B**	C***	A'*	B'**	C'***
1. A Study of the Seasons	4.5	7.5	8	1	1	2
2. A Study of the Heavens	2	1	2	2	2	3
3. Measurement and Significant figures	11	6	9	12	7.5	7
4. Mass, Volume, and Density	10	9	4	8.5	7.5	4
5. Work and Power	6	5	1	5	3	1
6. Simple Machines	3	3	3	10	12	11
7. Pressure and Barometer	4.5	10	7	8.5	9	9
8. Boyle's Law	12	11	5.5	11	10	6
9. Heat	7	4	10	6	4.5	5
10. Weather and Weather Maps	1	2	12	3	4.5	12
11. The Electric Battery Cell	9	12	11	4	6	10
12. Sound: Wavelength and Velocity	8	7.5	5.5	7	11	8

*A & A' Interest
**B & B' General Education Contribution
***C & C' Helpfulness

In Table III, both semester evaluation results in which students ranked the experiments for interest, general education contribution, and helpfulness in the lecture course, indicate generally consistent agreement for both semesters. Using the Spearman formula to determine the rank correlation coefficients for the student rankings of experiments for both semesters, the results are presented in Table IV.

TABLE IV

RANK CORRELATIONS (SPEARMAN FORMULA) BETWEEN FALL, 1954, AND SPRING, 1955, RANKINGS OF LABORATORY EXPERIMENTS FOR INTEREST, GENERAL EDUCATION CONTRIBUTION, AND HELPFULNESS

Experiments Evaluated for	Correlation Coefficient*
Interest	0.6032
General Education Contribution	0.2745
Helpfulness	0.5065

*E. F. Lindquist, Statistical Analysis in Educational Research, p. 247. New York: Houghton-Mifflin Co., 1940.

Experiment 10, "Weather and Weather Maps," was ranked first in interest by the students in the Fall (1954) semester and third by the students in the Spring (1955) semester. Experiment 2, "A Study of the Heavens," was ranked second in interest by both groups. Experiment 3, "Measurement and Significant Figures," and Experiment 8, "Boyle's Law, received the lowest interest ranking, either eleventh or twelfth in each semester.

Experiment 2, "The Study of the Heavens," was ranked first by the Fall sections and second by the Spring sections for general education contribution. A lesser degree of agreement between the semesters. appears for the lowest ranking for general education contribution. The Fall semester sections ranked Experiment 8, "Boyle's Law," and

Experiment 11, "The Electric Battery Cell," as eleventh and twelfth, respectively. Experiment 6, "Simple Machines," and Experiment 12, "Sound: Wavelength and Velocity," were ranked twelfth and eleventh, respectively for general education contribution by the Spring sections and Experiment 8, "Boyle's Law," was tenth.

Both the Fall and Spring sections ranked Experiment 5, "Work and Power," the most helpful (first) and Experiment 10, "Weather and Weather Maps," as the least helpful (twelfth).

The rankings given the experiments for interest indicate that the subjects of the "heavens" and of the "weather" were most interesting. Similarly, those same experiments were ranked high by the students in terms of the general education contribution. It is important to point out, however, that, although the experiment concerning the "heavens" was ranked high for helpfulness in the lecture course, the experiment concerning "weather" received the lowest rating. As an explanation of this disagreement, it must be pointed out that the topic of weather did not receive emphasis at that time in the lecture course. The inclusion of the "weather" experiment departed from the experiment preparation criterion of immediate relation to the lecture course. It was included in the list of experiments as an exception to supplement the lecture material on heat. These data suggest that the students of both semesters critically evaluated the experiments in terms of the rating classifications.

The rankings provide information concerning areas both of greatest student interest and of greatest value to the students. Conversely, those areas of least interest and of least value are indicated. Information of this kind will directly serve the purpose of guiding curriculum development. Experiments which received the lowest rankings in the three classifications represent areas in the laboratory program to which attention probably should be directed for possible curricular improvement.

Following the experiment ranking part of the questionnaire, Parts II, III, and IV were composed of questions which were designed to acquire specific information concerning the Physical Science laboratory program. The responses which the students of both semesters gave, were organized and tabulated for each semester and the data of both semesters were totaled for the year. These data are presented as Table V.

The data in Table V indicate that the students' responses of both semesters were approximately parallel. For that reason analysis is limited to the combined data for the year.

An estimate of how the laboratory program served students' purposes is reflected in the analyses of the items under Section A of Table V. Thirty-one students or 76 per cent indicated that they felt the laboratory was valuable to them. Thirty-five students or 85 per cent indicated that the laboratory experiences improved understanding of the lecture topics. Thirty-six students or 88 per cent felt the laboratory program provided experience in the application of elements of scientific method. Thirty-eight students or 93 per cent felt that problem solving, experimentally, by which answers to be acceptable must be based on evidence, was illustrated. Eighty-eight per cent of the students felt that the schedule of experiments closely agreed with the lecture schedule. Seventy-three per cent felt that 12 experiments were adequate to accompany the lecture course while 22 per cent felt that 12 experiments were too few.

TABLE V

SUMMARY OF RESPONSES OF THE EVALUATION SHEET FOR FALL, 1954, AND SPRING, 1955

A. How laboratory served students' purposes	No. of Responses Fall-54 Yes	No	Spring-55 Yes	No	Year 54-55 Yes	No	Per Cent*
1. Was the laboratory valuable? . . .	10	4	21	6	31	10	76
2. Did the laboratory schedule agree with lecture schedule?	9	5	27	0	36	5	88
3. Did the laboratory improve understanding of lecture topics? .	11	3	24	3	35	6	85
4. Did the laboratory afford illustration of scientific method?	14	0	22	5	36	5	88
5. Was scientific problem-solving illustrated?	14	0	24	3	38	3	93
6. Were 12 experiments adequate?							
Too many . . .	1		1		2		5
Sufficient . .	9		21		30		73
Too few	4		5		9		22
B. Physical aspects of the laboratory							
1. Was one hour of laboratory time sufficient?	2	12	10	17	12	29	(No) 71
2. What amount of time per laboratory period do you favor? . One Hour . .	2		7		9		22
Two Hours .	12		20		32		78
3. Was the laboratory equipment adequate for the experiments? . . .	14	0	27	0	41	0	100
4. Was any of the laboratory equipment too complex?	0	14	7	20	7	34	(No) 83
C. General questions.							
1. Would you recommend the laboratory course to other students?	11	3	25	2	36	5	88
2. Should the laboratory be required?	9	5	11	16	20	21	49
3. Would you elect the laboratory course to accompany Physical Science 192?	8	6	15	12	23	18	56
4. Is the Physical Science sequence a valuable contribution to the general education of undergraduates who are non-science majors?	13	1	25	2	38	3	93

*Indicates per cent for "Yes" column (Year) unless otherwise indicated.

Measures of the physical aspects of the laboratory are reflected in Section B of Table V. Twenty-nine students or 71 per cent did not think one hour was a sufficient amount of time to perform the experiments. Thirty-two students or 78 per cent favored a 2 hour laboratory period. Forty-one students or 100 per cent indicated that the laboratory equipment was adequate to accomplish the objectives of the experiments. Eighty-three per cent of the students did not think that the laboratory equipment was too complex to manipulate or understand.

General evaluative questions are summarized in Section C of Table V. Thirty-six students or 88 per cent indicated that they would recommend the laboratory course to other students. Forty-nine per cent favored a required laboratory course for all students enrolling in the Physical Science lecture course. Fifty-six per cent indicated they would elect an accompanying laboratory course with the second semester lecture course if scheduling permitted. Thirty-eight of the 41 students or 93 per cent felt that the Physical Science lecture course was a valuable contribution to the general education of undergraduates who are non-science majors.

The final part of the questionnaire, Part V, requested student suggestions for the improvement of the laboratory course. In each questionnaire students wrote at least a paragraph and in each case they re-emphasized a point or points which had been covered in previous parts of the questionnaire.

Interpretation of student evaluation data.--As validation of the first experiment selection criterion, 85 per cent of the students felt that the laboratory schedule agreed with the lecture schedule. Eighty-five per cent of the students felt that the laboratory program provided experience in the application of elements of scientific method; this fact supported the second criterion employed in preparing the experiments. The third criterion concerning the amount of time necessary for the experiments (one hour) had poorest support in that 71 per cent did not feel that adequate time was available for the experiments and 78 per cent of the students favored a two-hour laboratory period, or double the time which was allotted for the experiments.

The fourth criterion concerning student participation was supported in that 93 per cent felt that experimental problem solving was illustrated. The fifth criterion which was employed in the selection and preparation of experiments required that the experiments be relatively simple yet capable of challenging the students. In support of the fifth criterion 76 per cent of the students felt that the laboratory improved their understanding of lecture topics. The last criterion concerning simplicity and economy of equipment and facilities received unanimous student agreement in that 100 per cent indicated that the laboratory equipment was adequate. In addition, 83 per cent did not think that the equipment was too complex either to manipulate or to understand.

Interpretation of the student questionnaire data must be treated cautiously, however. These data are derived from the opinions of students concerning professional questions of curricular evaluation. The subjective nature of the responses limits the value of the results although the responses do provide distinct evidence of student attitudes. Student variables, such as scholastic aptitude and background knowledge, are not measured in terms of how such factors influence answers which are opinions.

SUMMARY

The evaluation of the Physical Science laboratory program accompanying the first semester Physical Science lecture course at Wayne State University was conducted during both the Fall (1954) semester and the Spring (1955) semester, using a student questionnaire technique with those students enrolled in the laboratory course. The preparation of 12 laboratory experiments consistent with 6 criteria was the first step in preparation for the evaluation. A 50 item questionnaire entitled, "Evaluation Sheet for Physical Science 193," was the device by which the student opinion data were acquired at the end of each semester. Data were acquired concerning interest, general education contribution, helpfulness of the experiments, the value of the laboratory to the purposes of the students, physical aspects of the laboratory, and general questions relating to the Physical Science course. The data were summarized, tabulated, and analyzed in this chapter.

The experiments which were most interesting to the students, and also those which were least interesting, were identified. Experiments having the greatest and least general education contribution as indicated by the students, as well as experiments deemed most helpful to them in understanding the related lecture course topics, were identified. Five of the 6 criteria employed in preparing the experiments were supported in the analyses of students' responses while one was not satisfactorily supported. The interpretation of the responses indicated relatively strong and favorable student opinion of the laboratory program, with the qualification, however, that the subjective nature of the data limits the value of the results.

CHAPTER III

AN EXPERIMENTAL TEST OF A METHOD FOR THE SELECTION OF A LABORATORY EXPERIMENT

The Problem

The purpose of this part of the investigation is to test experimentally, a method of selection of experiments for a Physical Science laboratory program which would provide desirable science-education experiences for the general education of college students.

Adequate evidence exists to indicate that some experiments do not perform the service they have been presumed to perform. The question arises as to how might effective experiments be selected? In order to test an experimental technique in this aspect of curriculum development, a method for the selection of a single experiment for a Physical Science laboratory program was planned. It was decided that, by using the judgment of a board of science specialists, an experiment illustrating related science principles most extensively in a given area would be the experiment selected for inclusion in a Physical Science laboratory program. It was decided that such an experiment would be used under trial conditions in a pilot study to test the specialist method of selecting a desirable laboratory experiment. To acquire a broader test of the method of selection, an expanded investigation was increased to four times the size of the pilot investigation.

The Pilot Investigation

Description of the pilot investigation.--The pilot investigation of the specialist-method of selecting a desirable laboratory experiment for inclusion in a Physical Science laboratory program was conducted during the Spring (1955) semester at Wayne State University.

The topical areas of heat and wave phenomena were considered as areas in which to test the proposed selection technique. Since the heat topic was treated in the lecture course near the middle of the semester and the heat experiments in laboratory would be scheduled to coincide with the lecture schedule, that topical area was selected in preference to wave phenomena which was treated at the end of the semester. By using a topic which occurred this early in the term, adequate time was acquired for pre- and post-testing and for caring for administrative details concerning the experimental work.

Of the 272 science principles identified by Wise[1], 29 were specifically classified as heat principles. The 29 heat principles from Wise's investigation were submitted to 4 professional science educators who had extensive experience with the Physical Science course at Wayne State University. Each specialist was asked to evaluate 8 heat experiments on a 5 point scale in terms of each experiment's applicability to the illustration of the 29 heat principles. A copy of the letter to each specialist in which the rating system was defined is included as Appendix B. As enclosures with the letter, the "Heat Principle - Heat Experiment Rating Sheet" and copies of the eight experiments were included. The rating

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[1]Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education." Unpublished Doctor's dissertation, University of Michigan, 1941.

sheet is included as Appendix C.

Seven heat experiments were selected as representative of experiments frequently presented in physics laboratory manuals under the topic of heat and presented similarly in Physical Science laboratory manuals. An eighth heat experiment which had been prepared by the author for use in the Wayne State University Physical Science laboratory program was included. Since the amount of time devoted to the topic of heat in the lecture schedule was approximately one week, only one heat experiment was required for the laboratory.

The 4 science specialists whose college teaching experience included at least 10 semesters of teaching the first semester Physical Science course, 3 of whom also had conducted Physical Science laboratory sections, rated each of the 8 experiments as to the degree each experiment illustrated each principle. The science specialists assigned each experiment one of the following numerical values:

0 - if the experiment did not illustrate the principle.

1 - if the experiment illustrated the principle only partially or poorly.

2 - if the experiment illustrated the principle fairly well.

3 - if the experiment illustrated the principle very well.

4 - if the experiment illustrated the experiment ideally.

The experiment which received the highest rating was the one deemed most desirable for inclusion in the laboratory program for the topic of heat. By the same system the experiment which received the lowest rating was deemed least desirable for inclusion.

Three student groups were used for this experimental part of the pilot investigation. Two of these groups were laboratory sections and one group was composed of students in lecture only, hereinafter identified as the non-laboratory group. It was desired that the groups be random and representative samples of the semester's Physical Science 191 population. The two laboratory sections which were used were the only sections scheduled for the Spring (1955) semester and, as a consequence, the entire laboratory population was available. On a random basis of the flip of a coin the groups were designated for the highest rated experiment and the lowest rated experiment. The laboratory group containing 14 students was so designated by that method to perform the highest rated experiment. The laboratory group containing 17 students was designated to perform the experiment which received the lowest score.

An examination by Dr. Harold E. Wise of the University of Nebraska was used for the pre-testing and the post-testing purposes of the 3 groups. The examination of heat principles is entitled "Science Examination: Heat Principles," and has 3 forms, Form A, Form B, and Form C. All 3 forms were administered on a trial basis in the Wayne State University and the Highland Park Junior College in the Spring (1954) semester in cooperation with Dr. Wise in a research study concerning science principles. Form B of the heat principles examination used in this study was taken by 202 college Physical Science students in the Detroit area when the test was administered in 1954. The mean of the Form B examination for the Detroit-area Physical Science students, established after the tests were machine-scored, was 20.75. The examination (Form B) is included as Appendix D.

Following a pre-test Laboratory Group I performed the heat experiment which was rated highest by the specialists, Laboratory Group II performed the heat experiment which received the lowest rating by the specialists, and the Non-Laboratory Group did not perform a heat experiment.

Four weeks after the pre-test, during which time the laboratory groups performed the experiments, the same examination was re-administered. During the interval between the pre-test and the post-test the heat topic was covered in the lecture course. The pre-test was used to determine initial ability in the topic.

The A. C. E. Psychological Examination was used for all students participating in the problem.

> The purpose of the American Council on Education Psychological Examination is to appraise what has been called scholastic aptitude or general intelligence, with special reference to the requirements of most college curricula.[2]

The A. C. E. Psychological Examination was employed to remove the differential effects due to scholastic aptitude or general intelligence. The examination provides three percentile scores. The Q score gives a measure of the student's capacity to do the type of quantitative thinking required of scientific and technical curricula. The L score gives a measure of the student's capacity to deal with words. The T score combines these two factors. Both the quantitative (Q) and linguistic (L) test scores are included in the tabular data of the Table VII.

For purposes of statistical inference, the null hypothesis provides the tentative assumption for the experiment. Applying the null hypothesis (H_0) relevant to this problem, it is assumed that there would be no difference in the measured outcome of the different treatments of the student groups, namely, the laboratory group using the highest rated experiment, the laboratory group using the lowest rated experiment, and

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[2]American Council on Education, <u>Psychological Examination for College Freshmen (1949 edition), Manual of Instructions</u>, p. 1. Princeton, New Jersey: Education Testing Service, 1949.

the non-laboratory group. With a relatively small number of cases in each group, a 5 per cent level of significance was set. In order to reject the hypothesis that any apparent differences between the different treatments was due to chance rather than the different treatments, the results would have to be such as to be possible on the basis of chance probability in 5 per cent or less instances.

The analysis of variance-covariance was used to determine and to remove such effects as differences between the groups which were due to general college aptitude and initial ability in the interpretation and application of heat principles from the differences in final achievements that might otherwise be attributed to differences in instructional treatment.

<u>The selection of the experiments for the pilot investigation</u>.--The total "principle" values assigned for each experiment (see Appendix C) by each specialist is indicated in Table VI.

TABLE VI

TOTAL ASSIGNED HEAT PRINCIPLE VALUES FOR EACH HEAT EXPERIMENT BY EACH SPECIALIST

SPECIALISTS	EXPERIMENTS							
	I	II	III	IV	V	VI	VII	VIII
Specialist A	19	23	25	21	27*	18**	19	14
Specialist B	7**	12	12	7**	12	18	31*	9
Specialist C	1**	2	3	8**	4	3	5	2
Specialist D	6**	10	13	11	10	11	16*	10
Total	33	47	53	47	53	50	71	35
EXPERIMENT RATING	8	5.5	2.5	5.5	2.5	4	1	7

* Highest Rated Experiment by Specialist.
** Lowest Rated Experiment by Specialist.

The composite values of the specialists' ratings were used to determine the highest rated and lowest rated experiments. Table VI is read as follows: 2 of the specialists gave Experiment VII the highest rating which agrees with the composite score rating; 3 of the specialists gave Experiment I the lowest rating which agrees with the composite score rating. Experiment VII, "Relative Humidity Determination by 'Bright Calorimeter' Method," received the highest composite rating in which the specialists assigned values for 18 principles. Conversely, Experiment I, "Law of Heat Exchange," received the lowest composite rating in which values for ten principles were assigned.

The reliability of the heat examination.--The reliability of the heat examination was established by determining the correlation between the two halves of the test as the result of calculating the maximum likelihood estimate. Using the maximum likelihood estimate equation[3], the reliability was found to be 0.941 which was assumed to be an acceptable level of reliability.

The validity of the heat examination.--The validity of the heat examination which was prepared by Wise was one of the considerations in its selection for use in this investigation. The author of the examination prepared it for the measurement of the understanding of heat principles by college Physical Science students. Based on the competancy of the author of the test and its applicability as a measurement device in this investigation, the validity of the examination was accepted on the curricular criteria of test content.

The testing program.--The test data were acquired and organized

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[3]Palmer O. Johnson, Statistical Methods in Research, p. 127. New York: Prentice Hall, Inc., 1949.

during the midpart of the Spring (1955) semester. The A. C. E. Psychological Examination was assigned the symbol, X_1. The heat principles examination pre-test data were designated as X_2. The post-test data were designated as Y. When analyses of the data were made, only the cases of those students, for which complete sets of data had been acquired, were considered. Consequently, Laboratory Group I contained ten students for experimental purposes whose data could be included in the statistical treatment. Similarly, Group II contained 12 students and the Non-Laboratory Group contained 13 students.

From the primary data the pre-test and post-test means for each group were calculated. The variances for the pre- and post-tests for each group were determined.

The means and variances for the science examination (both pre- and post-test administrations) together with the means of the groups for the A. C. E. Psychological Examination are presented in composite tabular form in Table VII.

TABLE VII

PRIMARY TEST STATISTICS FOR THE THREE GROUPS WHICH RECEIVED THE THREE TREATMENTS AND THE A. C. E. TEST SCORE DATA FOR EACH GROUP

Heat Principles Examination (Wise)								A. C. E. Psychological Examination
Group	N	Range		Means		Variances		Means
		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	
Lab Group I	10	12-25	17-29	18.80	22.50	21.23	11.97	112.7
Lab Group II	12	12-30	15-27	19.25	21.83	23.33	15.68	112.6
Non-Lab Group	13	10-32	8-27	21.92	23.00	30.14	28.2	104.0
Three Groups	35	10-32	8-29	20.114	22.457	27.24	19.27	109.9
				Four Year College*				106.79

*American Council on Education, <u>Psychological Examination For College Freshman</u>: Norms Bulletin, p.11. Princeton, N. J.: Educational Testing Service, 1950.

Table VII shows that small consistent gains in science information were made by the groups under each of the three treatments.

To overcome the tendency of the variance of a small sample to be too small, the population variance was estimated by multiplying the variance by $\frac{N}{N-1}$. Since $\frac{N}{N-1}$ is greater than one, σ^2 is corrected in the right direction and shown as $\tilde{\sigma}^2$ in Table VIII.

TABLE VIII

PILOT INVESTIGATION VARIANCES ADJUSTED FOR SMALL SAMPLE SKEWNESS FOR THE THREE GROUPS

Group	N	σ^2 Variance of Samples		$\tilde{\sigma}^2$ Estimate of Variance of Population	
		Pre-Test	Post-Test	Pre-Test	Post-Test
Lab Group I	10	21.23	11.97	23.59	13.30
Lab Group II	12	23.33	15.68	25.45	17.11
Non-Lab Group	13	30.14	28.2	32.65	30.55
Three Groups	35	27.24	19.27	28.04	19.84

In Table VIII the variances of the samples, after adjustment, tend to be the same as variances of large samples from the same population.

Testing the homogeneity of the groups of measurements of the pilot investigation.--To employ the analysis of variance-covariance an assumption that the standard deviation is constant must be made and this suggests that the variability of the scores is the same in each section. Since this may not be true a scheme for testing the homogeneity of the groups of measurements must be applied. For this purpose the L_1 - Homogeneity Test[4] was applied to the scores of the post-test of the heat principles examination in the pilot investigation. The test of the hypothesis

[4]Ibid., pp. 231-232.

$$H_o: \sigma_S = \sigma$$

was made, where σ_S denotes the standard deviation of the scores in the section. It was found that $L_1 = 0.9328$ with 11 degrees of freedom where k (number of groups) equaled 3. Since $P > .05$, the hypothesis H_o was accepted and is the basis for the conclusion that the groups participating in the pilot investigation were of equal variability. This provides basis for proceeding to the analysis of variance-covariance.

Analyses of variance-covariance in the pilot investigation.--Employing as a criterion the post-test results of the science examination of heat principles, the three groups received parallel measurements. Since scholastic aptitude and initial ability could conceivably influence each student's response to the criterion, these individual differences were controlled by using the A. C. E. Psychological Examination scores and science examination pre-test scores. By using these scores as control variables in the analysis of covariance, the possible bias introduced by individual differences was removed in so far as these factors represent the differences in question.

Using the post-test as the criterion for the evaluation of the relative effect on students of the three treatments, the null hypothesis (H_o) that no significant variations would be in evidence from the post-test data was tested.

The analysis of variance-covariance[5] for the post-test adjusted for the A. C. E. Psychological Examination is presented as

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[5]William G. Cochran and Gertrude M. Cox. Experimental Designs, pp. 78-82. New York: John Wiley and Sons, Inc., 1950.

Table IX.

TABLE IX

ANALYSIS OF VARIANCE-COVARIANCE FOR THE POST-TEST (Y) ADJUSTED FOR A. C. E. (X_1)

Source of Variation	D.F.	X^2	X_1Y	Y^2	Residuals D.F.	Residuals S.S. (Y adj.)	Residuals M.S.	Residuals F.	Hypothesis (H_1)
Treatments	2	815	-76	9	2	33	16.5	1.17	P <.05 Accepted
Error	32	14,593	1,863	666	31	435	14.03		
Total	34	15,408	1,787	675	33	468			

The null hypothesis (H_1) that no significant variations would be in evidence in the post-test due to scholastic aptitude was made. Applying the F-test to the adjusted treatment means, expressed by the ratio of the residual mean squares, with 2 and 31 degrees of freedom.

$$F = \frac{16.5}{14.03} = \underline{\underline{1.17}}$$

At the 5 per cent level of significance this ratio of the variances indicates acceptance of the null hypothesis (H_1).

The analysis of variance-covariance of the post-test adjusted for the pre-test is presented as Table X.

TABLE X

ANALYSIS OF VARIANCE-COVARIANCE FOR THE POST-TEST (Y) ADJUSTED FOR PRE-TEST (X_2)

Source of Variation	D.F.	Y^2	YX_2	X_2^2	Residuals D.F.	Residuals S.S. (Y adj.)	Residuals M.S.	Residuals F.	Hypothesis (H_2)
Treatments	2	9	19	69	2	66	33	2.08	P <.05 Accepted
Error	32	666	392	885	31	492	15.87		
Total	34	675	411	954	33	558			

The null hypothesis (H_2) that no significant variations would be in evidence in the post-test due to initial ability was made. Applying the F-test to the adjusted treatment means, expressed by the ratio of the residual mean squares, with 2 and 31 degrees of freedom.

$$F = \frac{33}{22.93} = \underline{\underline{2.08}}$$

At the 5 per cent level of significance this ratio of variances indicates acceptance of the null hypothesis (H_2).

The complete analysis of the variance-covariance[6] of the post-test scores, partialing out the joint effect of scholastic aptitude and initial ability is presented as Table XI.

TABLE XI

COMPLETE ANALYSIS OF VARIANCE-COVARIANCE (PARTIALING OUT THE EFFECTS FOR X_1 & X_2; TEST OF SIGNIFICANCE WITH REDUCED Y^2)

Source of Variation	D.F.	Y^2	X_1^2	X_2^2	X_1Y	X_2Y	X_1X_2	Adj. Y^2	Reduced D.F.	Reduced S.S.	Reduced M.S.	Reduced F.	Hypothesis (H_0)
Treatment	2	9	815	69	-76	19	-229	13.9	2	13.9	6.95	.53	P ∢.05
Error	32	666	14,593	885	1863	392	1910	393.4	30	393.4	13.1		
Total	34	675	15,408	954	1787	411	1681	407.3	32				Accepted
Coef.-for adj Y^2 (err.		1	.0095	.0531	-.1950	-.4610	.04493						
Coef.-for adj Y^2 (tot.		1	.0073	.07857	-.1708	-.5606	.04788						

The null hypothesis (H_3) that no significant variations would be in evidence in the post-test for the three treatments after the effects of scholastic aptitude and initial ability were partialed out was made. Applying the

[6] Palmer O. Johnson, *op. cit.*, pp. 310-324.

F-test to the reduced treatment means, expressed by the ratio of the reduced mean squares, with 2 and 30 degrees of freedom.

$$F = \frac{6.95}{13.1} = \underline{\underline{.53}}$$

At the 5 per cent level of significance this ratio of the variances indicates acceptance of the null hypothesis (H_3).

The null hypothesis (H_0) is accepted. The statistical treatment of the data from the experiment using the heat topic provides the basis for stating that no significant variations were apparent for the 3 pedagogical treatments among the 3 groups.

When the means of the post-tests for the three treatments were adjusted by the use of regression coefficients, "t"-tests indicated that differences between the means were not significant. Hence, the differences in the means of the unadjusted post-tests for the three treatments (see Table VII) are accounted for by the differences in prior knowledge of the topic and the initial ability of the students in the experimental groups.

The Expanded Investigation

Description of the expanded investigation.--The expanded investigation was conducted during the Spring (1956) semester at Wayne State University. It followed the same pattern as the pilot investigation although some modifications were introduced.

The topical areas of mechanics, heat, electricity, and wave phenomena were the areas on which tests of the selection technique were conducted. The 4 areas provided 4 additional sources of data to augment the findings of the pilot investigation.

From the 272 science principles identified by Wise[7], 4 lists of principles specific to the areas of mechanics of solids, heat, electricity, and wave phenomena were prepared. Each list of principles was submitted to the four science specialists who evaluated the lists in terms of the applicability of those principles to the selected topical areas of the Physical Science course. Of 22 principles concerning mechanics of solids, 17 were selected by the specialists for their applicability to the topic in the course and 2 principles were added by the specialists. (See Appendix E). Of 29 principles concerning heat, all were retained and used in an identical manner as in the pilot investigation. (See Appendix C). Of 38 principles concerning magnetism, static electricity, and current electricity, 28 principles were selected. (See Appendix F). Of 44 sound and light principles, 26 were selected as applicable to the topical area of wave phenomena. (See Appendix G).

Using the same rating scheme as employed in the pilot investigation, the four specialists rated experiments for each topical area in terms of the applicability of the principles of the appropriate list. The ratings made in the pilot investigation were used for the heat experiments. Four conventional electrical experiments on the list of electrical experiments were evaluated and, in addition, one experiment composed of 2 films was evaluated. The lists of experiments which were rated are presented in Appendix C (Heat), Appendix E (Mechanics), Appendix F (Electricity), and Appendix G (Wave Phenomena).

The 3 pedagogical treatments employed in the pilot investigation were repeated for each topical area, namely, one laboratory section using the

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[7]Harold E. Wise, op. cit., pp. IV & 767.

experiment which received the highest rating, one laboratory section using the experiment which received the lowest rating, and a non-laboratory group which was composed of students in lecture only.

The A. C. E. Psychological Examination was used for all students participating in the investigation to determine differential effects due to scholastic ability. For pre-testing and post-testing the 3 groups in each of the 4 topical areas, examinations in each topical area were prepared by the investigator to test students for understanding of the science principles included in the principle list for that area. The pre-test in each case was employed to determine initial ability in the topic. The post-test was used as the criterion. Validities and reliabilities for the four science examinations were established and are presented subsequently. The mechanics, heat, electricity, and wave phenomena examinations are included as Appendices H, I, J, and K.

The null hypothesis was employed for purposes of statistical inference to each of the four topical areas of the expanded investigation. The relevant null hypothesis in each case assumed that there would be no difference in the measured outcome of the different treatments of the student groups, namely, the laboratory group using the highest rated experiment, the laboratory group using the lowest rated experiment, and the non-laboratory group. The 5 per cent level of significance was set due to the relatively small size of each group.

<u>The selection of the experiments for the expanded investigation.</u>--The highest rated and lowest rated experiments for each topical area were determined from the ratings of the specialists. For the mechanics area the results for the principles-experiments rating are indicated in Table XII. The list of principles and the experiments are presented as

Appendix E.

TABLE XII

TOTAL ASSIGNED MECHANICS PRINCIPLE VALUES FOR EACH MECHANICS EXPERIMENT BY EACH SPECIALIST

Specialists	Experiments				
	I	II	III	IV	V
Specialist A	14*	10	10	1**	2
Specialist B	16*	13	11	2**	3
Specialist C	8*	1	4	1	0**
Specialist D	32*	24	19	4**	8
Total	70	48	44	8	13
EXPERIMENT RATING	1	2	3	5	4

* Highest rated experiment by specialist.
** Lowest rated experiment by specialist.

The composite values of the specialists' ratings were used to determine the highest and lowest rated experiments. Table XII is read as follows: all four specialists gave Mechanics Experiment I, "Work and Power: Stair-step Experiment," the highest score and it had the highest composite score. Mechanical Experiment IV, "Concurrent Forces," received the lowest rating by three specialists and had the lowest composite score. Experiment I was assigned values for 10 of the 19 principles. Conversely, Experiment IV was assigned values for only two of the mechanics principles.

For the topical area of heat the ratings in the pilot investigation were used. The data for the heat experiments were presented in Table VI.

The results for the electric principles-electric experiments are presented in Table XIII. The list of principles and the experiments are presented as Appendix F.

TABLE XIII

TOTAL ASSIGNED ELECTRICITY PRINCIPLES VALUES FOR EACH ELECTRICITY EXPERIMENT BY EACH SPECIALIST

Specialists	Experiments				
	I	II	III	IV	V
Specialist A	9	10	50*	8**	8**
Specialist B	10	12	51*	9**	9**
Specialist C	0**	5	37*	4	4
Specialist D	7**	10	58*	10	11
Total	26	37	196	31	32
EXPERIMENT RATING	5	2	1	4	3

* Highest rated experiment by specialist.
** Lowest rated experiment by specialist.

Table XIII is read as follows: all four specialists gave Electrical Experiment III, "Two Films on Electricity: (1) The Electron, and (2) Electrodynamics," the highest score and it had the highest composite score. Electrical Experiment I received the lowest rating by two specialists and had the lowest composite score. Experiment III received values for 24 of the 28 principles. Conversely, Experiment I received values for only four principles.

The results of the wave phenomena principles-wave pehnomena experiments are presented in Table XIV. The list of principles and the experiments are presented as Appendix G.

Table XIV is read as follows: three specialists gave Wave Phenomena Experiment I, "Sound: Wavelength and Velocity," the highest score and it had the highest composite score. Wave Phenomena Experiment IV, "Light: The Photometer," received the lowest rating by two specialists and it had the lowest composite score. Experiment I received values for 12 of the 26 principles. Conversely, Experiment IV received values for only six of the principles.

TABLE XIV

TOTAL ASSIGNED WAVE PHENOMENA PRINCIPLES VALUES FOR EACH WAVE PHENOMENA EXPERIMENT BY EACH SPECIALIST

Specialists	Experiments						
	I	II	III	IV	V	VI	VII
Specialist A	35*	4**	5	5	12	8	8
Specialist B	21*	14	11	6	9	9	4**
Specialist C	2	4*	2	0**	2	1	2
Specialist D	36*	18	16	4**	10	8	12
Total	94	40	34	15	33	26	26
EXPERIMENT RATING	1	2	3	7	4	5-6	5-6

* Highest rated experiment by specialist.
** Lowest rated experiment by specialist.

<u>The reliabilities of the science examination.</u>--The reliabilities of the 4 science examinations were established by determining the correlation between 2 halves of each post-test. Calculating the maximum likelihood estimate provided an optimum estimate of the reliability of each examination and these data are presented in Table XV.

TABLE XV

RELIABILITIES OF THE SCIENCE EXAMINATIONS IN THE EXPANDED INVESTIGATION

Examination	Reliability
Mechanics Principles Examination	0.989
Heat Principles Examination	0.934
Electricity Principles Examination	0.975
Wave Phenomena Principles Examination	0.959

The reliabilities of these four science examinations were considered to be satisfactory.

<u>The validities of the science examinations.</u>--The validities of

the 4 science examinations used in the expanded investigation were based on the pooled judgments of 3 of the science specialists. The validity of each examination was accepted on the curricular criteria of test content[8].

The testing program.--The test data were acquired and organized during the Spring (1956) semester. The A. C. E. Psychological Examination scores of the participating students were acquired from the Wayne State University Testing Center. The science-principles examinations in mechanics, heat, electricity, and wave phenomena were administered for the participating groups both as pre-tests and post-tests. This involved a total of 32 administrations of tests to the different groups of students. The 2 laboratory sections which were used, received pre-tests and post-tests for each of the 4 examinations. The non-laboratory groups were rotated in a manner so that the same 2 non-laboratory groups which took pre- and post-tests for one examination were replaced by another 2 groups for the next examination. This was an administrative necessity in order that no two particular groups would lose all the time necessary for the tests from their weekly quiz sections. The procedure served as an advantage, however, in that a broad testing program resulted.

From the primary data acquired from the testing program the pre-test and post-test means of each group for each test were calculated and the variances were determined. The means and variances for the science examinations (both pre- and post-test administrations) together with the means of the groups for the A. C. E. Psychological Examination are presented in composite tabular form in Table XVI. Analysis of these

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[8]H. H. Remmers and N. L. Gage, Educational Measurement and Evaluation, p. 197. New York: Harper and Brothers, 1943.

TABLE XVI

PRIMARY TEST STATISTICS FOR THE THREE GROUPS WHICH RECEIVED THE THREE TREATMENTS FOR EACH OF THE FOUR TOPICAL AREAS AND THE A. C. E. TEST SCORE DATA FOR EACH GROUP

Science Principles Examinations									A. C. E. Psychological Examination
			Range		Means		Variances		
Examination	Groups	N	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Means
1. Mechanics Principles	Lab. Group I	14	14-25	17-36	19.07	23.71	9.495	23.20	116.14
	Lab. Group II	14	12-33	19-33	22.57	26.14	39.24	19.45	111.50
	Non-Lab. Group	26	8-33	10-34	16.54	21.27	37.86	34.19	100.62
	Three Groups	54	8-33	10-36	18.76	23.17	37.03	33.01	107.46
2. Heat Principles	Lab. Group I	13	9-17	11-20	13.46	14.54	8.09	9.33	115.69
	Lab. Group II	13	8-22	11-21	13.92	16.00	23.72	9.69	114.38
	Non-Lab. Group	36	7-20	10-27	13.64	16.86	9.66	17.25	105.97
	Three Groups	62	7-22	10-27	13.66	16.19	11.75	14.31	109.77
3. Electricity Principles	Lab. Group I	13	11-20	10-23	14.31	16.85	8.96	18.23	115.69
	Lab. Group II	13	8-24	10-23	15.54	17.62	16.53	14.77	114.38
	Non-Lab. Group	27	4-26	9-26	11.67	18.81	24.10	15.65	102.26
	Three Groups	53	4-26	8-26	13.27	18.04	17.55	16.75	108.53
4. Wave Phenomena Principles	Lab. Group I	13	10-28	15-37	18.69	22.77	19.63	28.78	115.69
	Lab. Group II	13	12-28	15-35	18.46	25.31	30.28	40.47	114.38
	Non-Lab. Group	28	5-28	15-33	16.29	22.18	24.61	25.91	108.61
	Three Groups	54	5-28	15-37	17.39	23.08	27.89	31.77	111.70
								Four Year College*	106.79

*American Council on Education, Psychological Examination for College Freshmen (1949 Edition): Norms Bulletin, pp. 11, 14, 19. Princeton, New Jersey: Educational Testing Service, 1950.

data indicate that small consistent gains in science information were made by the groups under each of the treatments.

<u>Testing the homogeneity of the groups of measurements of the expanded investigation.</u>--The L_1-Homogeneity Test was applied to the scores of the post-tests of the science-principles examinations for the groups participating in the expanded investigation. The test of the hypothesis

$$H_0: \sigma_s = \sigma$$

was made in each instance and the findings are presented in Table XVII.

TABLE XVII

L_1-HOMOGENEITY TESTS OF THE SCORES OF THE SCIENCE EXAMINATIONS (POST-TESTS) FOR THE GROUPS PARTICIPATING IN THE EXPANDED INVESTIGATION

Examination	No. of Groups k	L_1	d.f.	Hypothesis $H_0: \sigma_s = \sigma$
Mechanics Principles	3	0.9708	15.476	$P > .05$; Accepted
Heat Principles	3	0.9328	15.367	$P > .05$; Accepted
Electricity Principles	3	1.0440	14.626	$P > .05$; Accepted
Wave Phenomena Principles	3	0.9827	14.728	$P > .05$; Accepted

Since $P > .05$ in each test, the hypothesis H_0 was accepted in each. These findings are the bases that the groups participating in the expanded investigation were of equal variability. These findings provide bases for proceeding to the analyses of variance-covariance.

The adjustment of the variances of the samples used in the expanded investigation was made by multiplying the variances of the samples by $\frac{N}{N-1}$. These data are presented in Table XVIII.

In Table XVIII the variances of the samples which were used in the expanded investigation, after adjustment, tend to be the same as variances of large samples from the same population.

TABLE XVIII

EXPANDED INVESTIGATION VARIANCES ADJUSTED FOR SMALL SAMPLE SKEWNESS FOR THE THREE GROUPS FOR EACH OF THE FOUR TOPICAL AREAS

Examination	Groups	N	Variance of Sample		Estimate of Variance of Population	
			Pre-Test	Post-Test	Pre-Test	Post-Test
1. Mechanics Principles	Lab. Group I	14	9.495	23.20	10.225	24.98
	Lab. Group II	14	39.24	19.45	42.26	20.95
	Non-Lab. Group	26	37.86	34.19	39.37	35.56
	Three Groups	54	37.03	33.01	37.73	33.63
2. Heat Principles	Lab. Group I	13	8.09	9.33	8.76	10.11
	Lab. Group II	13	23.72	9.69	25.70	10.50
	Non-Lab. Group	36	9.66	17.25	9.94	17.74
	Three Groups	62	11.75	14.31	11.94	14.54
3. Electricity Principles	Lab. Group I	13	8.96	18.23	9.71	19.75
	Lab. Group II	13	16.53	14.77	17.91	16.00
	Non-Lab. Group	27	24.10	15.65	25.03	16.25
	Three Groups	53	17.55	16.75	17.89	17.07
4. Wave Phenomena Principles	Lab. Group I	13	19.63	28.78	21.27	31.18
	Lab. Group II	13	30.28	40.47	32.80	43.84
	Non-Lab. Group	28	24.61	25.91	25.52	26.87
	Three Groups	54	27.89	31.77	28.42	32.37

Analysis of variance-covariance in the expanded investigation.--Since this investigation was concerned with a technique for the selection of laboratory experiments, and since, from the testing program, the evidence indicates small consistent gains in science information in all groups, the question remains as to how much the different pedagogical treatments contributed to the gains. Using the post-test of each of the 4 parts of the expanded investigation as the criterion for the evaluation of the relative effect on students of the 3 treatments, the null hypothesis (H_0), that no significant variations would be in evidence from the post-test data, was tested.

When the post-tests of each topical area were adjusted for the

A. C. E. scores, employing the analysis of variance-covariance technique, the F-ratio at the 5 per cent level was not significant in each case. The null hypothesis in each case was accepted. F-ratios and hypotheses of the post-tests adjusted for the A. C. E. scores are presented in Table XIX.

TABLE XIX

F-RATIOS AND NULL HYPOTHESES FROM THE ANALYSES OF VARIANCE-COVARIANCE FOR THE POST-TESTS (Y) ADJUSTED FOR A. C. E. (X_1)

Topical Areas	F-Ratios	Null Hypotheses
Mechanics	2.5	P $<$ .05; Accepted
Heat	1.54	P $<$ .05; Accepted
Electricity	2.63	P $<$ .05; Accepted
Wave Phenomena	.45	P $<$ .05; Accepted

When the post-tests of each topical area were adjusted for the pre-tests, employing the analysis of variance-covariance technique, the F-ratios were not significant in three cases. In one case, however, the electricity post-test adjusted for the electricity pre-test, the ratio was at the margin of statistical significance. The null hypotheses for the three topical areas, mechanics, heat, and wave phenomena, were accepted. In the case of electricity, however, because of the F-ratio, the hypothesis remains in doubt. F-ratios and hypotheses for the post-tests adjusted for the pre-tests are presented in Table XX.

TABLE XX

F-RATIOS AND NULL HYPOTHESES FROM THE ANALYSES OF VARIANCE-COVARIANCE FOR THE POST-TESTS (Y) ADJUSTED FOR PRE-TESTS (X_2)

Topical Areas	F-Ratios	Null Hypotheses
Mechanics	.66	P $<$ .05; Accepted
Heat	.83	P $<$ .05; Accepted
Electricity	3.8	Remains in doubt
Wave Phenomena	.38	P $<$ .05; Accepted

By similtaneously partialing out the effects of the pre-tests and A. C. E. scores on the post-tests by a complete analysis of variance-covariance technique, the F-ratios and hypotheses remained in agreement with the previous results and are presented in Table XXI.

TABLE XXI

F-RATIOS AND NULL HYPOTHESES FOR THE COMPLETE ANALYSIS OF VARIANCE-COVARIANCE PARTIALING OUT THE EFFECTS FOR THE PRE-TESTS AND A. C. E. SCORES

Topical Areas	F-Ratios	Null Hypotheses
Mechanics	1.42	P .05; Accepted
Heat	1.25	P .05; Accepted
Electricity	3.78	Remains in doubt
Wave Phenomena	.47	P .05; Accepted

F-ratios were significant in 3 cases at the 5 per cent level. The F-ratio for the electricity area was at the margin of statistical significance. The null hypothesis for each case was accepted, except in the electricity case which remained in doubt.

When the means of the post-tests for the 3 treatments in each of the 4 topical areas were adjusted by the use of regression coefficients, "t"-tests indicated that differences between the means were not significant. Hence, the differences in the means of the unadjusted post-tests for the 3 treatments in each of the 4 topical areas (see Table XVII) are accounted for by the differences in prior knowledge of the topic and initial ability of the students in the experimental groups.

SUMMARY

The purpose of Chapter III was to test experimentally, a method of selection of experiments for a Physical Science laboratory program.

Initially, a pilot investigation was made using the topical area of heat in an existing Physical Science course. Eight heat experiments were evaluated by 4 science specialists who had taught the Physical Science course. They rated the experiments in terms of the degree to which each experiment illustrated each of 29 heat principles. From the evaluation by the specialists the experiments receiving the highest and lowest ratings were determined. Three student groups, 2 laboratory groups and one non-laboratory group, were used to test the science principles--specialist technique of selecting experiments.

The laboratory groups represented the total enrollment in the Physical Science laboratory course, Physical Science 193, at Wayne State University during the Spring (1955) semester. Each group was a laboratory section. The non-laboratory group was composed of students who were enrolled in the lecture course, Physical Science 191, and who were not enrolled in the laboratory sections.

The data sources were the students' scores from the A. C. E. examination and a science examination of heat principles. The science examination was administered as a pre-test, prior to the treatment of the topic of heat in the lecture and laboratory courses, and as a post-test a month later following the treatment of the heat topic in lecture and the performance of the heat experiments in laboratory. The experiment which received the highest rating by the specialists was conducted by one laboratory section while the experiment which received the lowest rating was conducted by the other laboratory section.

The statistical analyses which were applied to the test data of the groups adjusted the post-test scores for the pre-test which indicated initial knowledge and for the A. C. E. Psychological Examination scores which indicated general college aptitude. The data were treated in three steps, namely, the analysis of variance-covariance for the post-test (the criterion) adjusted for the A. C. E. Psychological Examination scores, the analysis of variance-covariance for the post-test adjusted for the pre-test scores, and the complete analysis of variance-covariance in which the effects of the A. C. E. and pre-test were partialed out and the test of significance of the reduced means squares of the criterion was made.

The null hypothesis, that no significant variations would be in evidence by the three pedagogical treatments, was accepted. The results of the statistical treatment of the data of the pilot investigation did not provide an adequate measure of the effectiveness of the science principles-specialist rating technique of selection of laboratory experiments. The results are the bases for a question concerning the existence of a laboratory program, regardless of the kind of experiment used.

Employing the experimental design of the pilot investigation, an expanded investigation was conducted a year later in which the scope of the investigation was quadrupled. Four topical areas of mechanics, heat, electricity, and wave phenomena were utilized.

Applying the "t"-test to the adjusted means of the post-tests for the three treatments in the topical area of heat in the pilot investigation and the topical areas of mechanics, heat, electricity, and wave phenomena in the expanded investigation, no case was found in which the differences between the means were significant. The differences which exist between the unadjusted means of the post-tests are accounted for by the differences in prior knowledge of the respective topic and initial ability of the students in the experimental groups.

The statistical analyses, that of analysis of variance-covariance, in the expanded investigation corroborated the results of the pilot investigation, generally. Of 12 null hypotheses which were applied, 10 were accepted, while 2 were marginal and remained in doubt. The results of the statistical treatment of the data of the expanded investigation duplicated the evidence of the pilot investigation, i. e., that the results did not provide an adequate measure of the effectiveness of the specialist selection technique of laboratory experiments.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Methods Employed

The purposes of this investigation were (1) to evaluate a laboratory program accompanying a college Physical Science course at Wayne State University, and (2) to test experimentally a method of selection of laboratory experiments which would provide desirable science-education experiences for the general education of college students.

For the first part of the investigation 12 experiments were prepared during the summer of 1954 in accordance with 6 criteria for the selection of Physical Science laboratory experiments. The experiments were used in the Physical Science laboratory sections during both semesters of the 1954-1955 school year, except for a substitution for one experiment during the second semester. A questionnaire was employed at the end of each semester to obtain student opinion as a basis for evaluation of the laboratory course. The 12 experiments were rated by the students in terms of interest, general education contribution, and helpfulness for the lecture course. The students also evaluated the value of the laboratory program in helping them understand the lecture course, the value of the physical aspects of the laboratory, and the general value of the Physical Science course. The results from the student opinion questionnaires are the bases for the conclusions which are submitted concerning the evaluation of the laboratory program.

To test experimentally a method by which laboratory experiments could be selected, the topical area of heat was used for specific experimentation in a pilot investigation (Spring, 1955), and topical areas of mechanics, heat, electricity, and wave phenomena were used in an expanded investigation a year later (Spring, 1956). Initially, a group of specialists were requested to rate 8 heat experiments as to how well those experiments illustrated each of 29 principles. The experiment which was assigned to the greatest number of heat principles and which received the highest composite score and the experiment which was assigned to the fewest principles and received the lowest composite score, were used in the pilot investigation. Two laboratory groups and one non-laboratory group participated in both the pilot and expanded studies, One laboratory group performed the experiment or experiments which the specialists rated highest and which also illustrated the most principles. The other laboratory group performed the experiment or experiments which the specialists rated lowest and which also illustrated fewest principles. The non-laboratory group received only the lecture course treatment in the topical area; the two laboratory groups received both lecture and laboratory. All three groups were pre-tested on principles of heat. The same heat principles examination was employed as the criterion post-test. The post-test scores were adjusted for the total scores on the A. C. E. Psychological Examination and for the pre-test scores in order to consider the general college aptitude and initial ability of the participating students. The data were treated statistically by an analysis of variance-covariance technique. This experimental scheme was repeated in the expanded investigation for the four topical areas of mechanics, heat, electricity and wave phenomena. The results of the experimental data are the bases for the conclusions concerning the selection technique which was tested.

Conclusions

The conclusions orient into three categories, namely, those derived from the laboratory evaluation based on student opinion data acquired by the questionnaire technique, those derived from the data acquired from the pilot and expanded experimental investigation concerning the selection of laboratory experiments, and general conclusions derived from the total investigation.

Conclusions from student questionnaire data.--The following conclusions are based on the student questionnaire evaluation data:

1. Ninety-three per cent of the students enrolled in the laboratory course during the 1954-1955 school year indicated that they considered the Physical Science course to be a valuable contribution to undergraduate general education for non-science majors. Therefore, in terms of student opinion, the Physical Science course is a valuable general education course.

2. Seventy-five per cent of the students felt the laboratory was valuable to them, 88 per cent indicated that they would recommend the laboratory course to other students, and 85 per cent indicated the laboratory helped their understanding of the lecture topics. These percentages of student opinion suggest that the laboratory is both valuable and helpful in understanding lecture course concepts.

3. Eighty-eight per cent of the students indicated that the laboratory had provided experience in application of elements of the scientific method. Ninety-three per cent indicated that problem-solving, experimentally, by which answers to be acceptable, must be based on evidence, was illustrated. From these data of student opinion, the implication

is that the laboratory is a pedagogical method by which scientific methods may be experienced by students and scientific attitudes may be inculcated.

4. Eighty-eight per cent of the laboratory students indicated that they felt the laboratory schedule agreed closely with the lecture schedule. By careful planning the laboratory experiments illustrating lecture topics can be scheduled to parallel closely the schedule of the lecture presentation.

5. Seventy-three per cent indicated that 12 laboratory experiments were adequate, 5 per cent thought 12 experiments were too many, while 22 per cent thought that number of experiments was not enough. Based on the amount of scheduled time which was available, 12 experiments were sufficient for the semester, although the data suggest more experiments might have been used to accompany the lecture course.

6. Seventy-eight per cent of the laboratory students indicated that they favored a two-hour period for laboratory. Seventy-one per cent indicated that the one-hour laboratory period was not sufficient time to perform the experiments. Even though the experiments which were used in each semester were expressly designed for one-hour laboratory periods, the two-hour laboratory period is deemed more desirable.

7. One hundred per cent of the students of both semesters felt the laboratory equipment and materials were adequate. Eighty-three per cent indicated that they did not consider the equipment too complex to manipulate or understand. Relatively simple equipment can be employed effectively to achieve Physical Science laboratory objectives.

These data consistently reflect a positive student estimate of laboratory as being both valuable and helpful to them, particularly in understanding the lecture course. These student opinion data provide a subjective measure of the laboratory program.

Conclusions from pilot and expanded investigations.--The following conclusions are derived from the pilot and expanded experimental investigations in which the laboratory-nonlaboratory methods were employed to evaluate the science principles-science specialist technique of selecting college Physical Science laboratory experiments:

1. Small, consistent gains were made in science information and knowledge of science principles under each of the pedagogical treatments, namely, lecture with laboratory using experiments which received the highest science principles ratings by science specialists, lecture with laboratory using experiments which received the lowest science principles ratings by science specialists, and lecture without laboratory.

2. A quantitative measure of the science principles-science specialist method for selecting the most effective experiments for inclusion in a college Physical Science laboratory program was not established. After the three conditions of pedagogical treatment the statistical results provided no significant variations in knowledge of science principles among the groups.

When the lecture-demonstration instructional technique is compared with the lecture-demonstration-laboratory technique, the evidence within the limits of this investigation shows no statistically significant difference. Because the laboratory program itself does not provide significantly better results as measured by the understanding of scientific principles, it is doubtful that any method for selecting experiments for a college Physical Science laboratory program could be identified as being better than any other method.

General conclusions.--General conclusions based on an interpretation of the results of the total investigation are presented as follow:

1. The opinion of students concerning the positive value of laboratory, a subjective evaluation, is a questionable measure when the objective results of experimental investigation indicate no statistical variation in knowledge of science principles among the groups which received different pedagogical treatments. The following points support this conclusion.

a. The statistical results of the examinations on science principles of the pilot and expanded investigations provide an objective test of the value of the laboratory to the students. The apparent value of the laboratory from the student opinion evaluation is not supported by the objective measure provided by the data from the pilot and expanded investigations.

b. As a consequence of the inconsistency between the student opinion data and the objective data, the student opinion data apparently have pronounced limitations in the evaluation of the laboratory program. Sophisticated, critical analysis of complex educational questions by freshman- and sophomore-level college students, represents a relatively unqualified and perhaps misleading source of information on which to base evaluations.

2. From the null hypotheses that no significant variations existed among the three groups in knowledge of scientific principles after the three different pedagogical treatments, evidence is provided which seems to support the conclusion that a Physical Science laboratory program is of little or no value to assist students in a general education Physical

Science course in the understanding of science principles.

It must be recognized, however, that abstract mental concepts, such as the understanding of science principles, were measured by objective testing devices. The experimental results do not preclude the possibility of acquisition of scientific attitudes, of problem-solving skills, or of manipulative skills. Similarly, the value which the laboratory might contribute to the retention of knowledge of science principles and to the ability to apply problem-solving skills to life situations would deserve consideration although these factors were not within the immediate scope of this investigation.

Recommendations

On the basis of the results and conclusions of this investigation it is recommended that:

1. Further studies should be made to determine the specific values which a laboratory program for a Physical Science course does provide, particularly in terms of quantified measures of such values as the acquisition of manipulative skills, of problem-solving abilities, and of scientific attitudes.
2. Experimental design for such studies should employ such mathematical techniques as analysis of variance-covariance, where applicable, in order that the research worker can compare the experimental results and draw conclusions with respect to the significance of such results.
3. Brief, well designed, home projects be developed to provide students with experiences in the application and demonstration of important principles of science and that the utilization of these projects be compared with more formal laboratory programs.

APPENDICES

APPENDIX A

EVALUATION SHEET FOR

PHYSICAL SCIENCE 193

EVALUATION SHEET FOR PHYSICAL SCIENCE 193

I. The following is a list of the experiments you conducted this term. Rate the experiments as indicated below.

Column A---By number (1 to 12) indicate the experiments in order of their interest to you, i.e., 1 (most interesting), to 12 (least interesting).

Column B---By number (1 to 12) indicate the experiments in order of their general education contribution to you, i.e., 1 (best contribution), 12 (poorest contribution).

Column C---By number (1 to 12) indicate the experiments in order of their helpfulness to you in Physical Science 191, i.e., 1 (most helpful), 12 (least helpful).

NAME OF THE EXPERIMENT	A	B	C
1. A study of the seasons.			
2. A study of the heavens.			
3. Measurement and significant numbers.			
4. Mass, volume, and density.			
5. Work and power.			
6. Simple machines.			
7. Pressure and the barometer.			
8. Boyle's law.			
9. Heat.			
10. Weather and weather maps.			
11. The electric battery cell.			
12. Sound: wavelength and velocity.			

II. The following questions are concerned with your evaluation of how the laboratory served your purposes. Please answer the questions by checking the alternatives:

A. Do you feel that the laboratory, generally, was valuable to you? . . . . YES___ NO___

B. Did the laboratory schedule of experiments closely agree with the lecture schedule? . . . . . YES___ NO___

C. Did the laboratory improve your understanding of lecture topics? . . . . YES___ NO___

D. Do you feel that the laboratory program provided experience in the application of the elements of scientific method? . . . . YES___ NO___

E. Do you feel that problem-solving, experimentally, by which answers, to be acceptable, must be based on evidence, was illustrated? . . . . YES___ NO___

F. Do you feel that the twelve laboratory experiments which were used were adequate to accompany the lecture course? . . . . TOO MANY ___
SUFFICIENT___
TOO FEW ___

III. The following questions are concerned with physical aspects of the laboratory. Please answer the questions by checking one of the alternatives:

A. Was one hour of laboratory time sufficient to perform the experiments? . . . . YES___ NO___

B. Based on the experiments you performed, in your judgment which amount of time per laboratory period do you favor? . . . . 1 hour ____
2 hours ____

C. Was the laboratory equipment employed adequate to accomplish the objectives of the experiments?. . . YES___ NO___

D. Was any of the laboratory equipment too complex for you to manipulate or understand? . . . . YES___ NO___

IV. The following questions are concerned with the future of the laboratory program in the physical science courses. Please answer the questions by checking one of the alternatives:

A. Would you recommend the laboratory course to other students? . . . . YES___ NO___

B. Do you favor requiring a laboratory program in physical science for all students who enroll in the course? . . . . YES___ NO___

C. If no conflicts exist in your program would you elect the second term laboratory course to accompany Physical Science 192? . . . . YES___ NO___

D. Do you feel that the physical science sequence is a valuable contribution to the general education of undergraduates who are non-science majors? . . YES___ NO___

V. If you have any suggestions which you feel would improve the laboratory course, please present them in a brief, explicit manner in the space below.

APPENDIX B

LETTER FORWARDED WITH RATING SHEET TO SCIENCE SPECIALISTS

19 February, 1955

Dear Sir:

This letter is to request your assistance in a phase of my doctoral investigation, being conducted at Wayne University. Because of your professional background in science and your extensive experience with the general education physical science course, I request that you serve as a rating authority of selected experiments and principles concerned with the topical area of heat.

This phase of the project concerns the rating of eight (8) selected heat experiments based on the criterion of how applicable they are to twenty-nine (29) heat principles included by Dr. Harold E. Wise in his list of two hundred and seventy (270) physical science principles for general education.

I am forwarding the following materials as enclosures:

1. Heat principle--heat experiment rating sheet.
2. Eight (8) heat experiments.

Please evaluate the eight (8) heat experiments on the rating sheet (encl. 1) based on a five point scale. Assign one of the numerical values indicated below to each experiment in terms of your judgment of its applicability to the illustration of each of the twenty-nine (29) heat principles listed.

Rating	Explanation of the rating
0	The experiment does not illustrate the principle.
1	The experiment illustrates the principle only partially and/or poorly.
2	The experiment illustrates the principle fairly well.
3	The experiment illustrates the principle very well.
4	The experiment illustrates the principle ideally.

The eight (8) experiments (encl. 2) are included for your convenience in referring to such details as you may desire to check.

Please feel free to comment on the rating sheets, experiments, rating scale or other aspects of the investigation. I will appreciate such comments.

Sincerely yours,

David A. Hilton

dah/rh
2 encls.

APPENDIX C

HEAT PRINCIPLES -

HEAT EXPERIMENTS RATING SHEET

HEAT PRINCIPLE - HEAT EXPERIMENT RATING SHEET

Name__________________________ Date_______________

Position____________________________

Institution__________________________

- -

Instructions: In each block beside the twenty-nine (29) principles, assign each experiment one of the following numerical values, viz.:

0 - if the experiment <u>does not</u> illustrate the principle.
1 - if the experiment illustrates the principle only <u>partially</u> or <u>poorly</u>.
2 - if the experiment illustrates the principle <u>fairly</u> well.
3 - if the experiment illustrates the principle <u>ideally</u>.

- -

HEAT PRINCIPLES / HEAT EXPERIMENTS	Heat Experiment I: Law of Heat Exchange	Heat Experiment II: Determining Specific Heat of Aluminum	Heat Experiment III: Heat of Fusion	Heat Experiment IV: Changing a Liquid to a Solid: Solidification	Heat Experiment V: Changing a Liquid to a Gas: Vaporization	Heat Experiment VI: Heat Loss by Evaporation and Solution	Heat Experiment VII: Relative Humidity Determination by "Bright Calorimeter" Method	Heat Experiment VIII: Heat Problem
1. The average speed of molecules increases with the temperature and pressure.								
2. Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.								
3. The total change in length of a metal bar is equal to its coefficient of linear expansion times the original length times the change of temperature in degrees Centigrade.								

	I	II	III	IV	V	VI	VII	VIII
4. A change in state of a substance from gas to liquid, liquid to solid, or vice versa, is usually accompanied by a change in volume.								
5. Substances which expand upon solidifying have their melting points lowered by pressure; those which contract upon solidifying have their melting points raised by pressure.								
6. Heat is liberated when a gas is compressed, and is absorbed when a gas expands.								
7. Heat is conducted by the transfer of kinetic energy from molecule to molecule.								
8. When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.								
9. Heat is transferred by convection, in currents of gases or liquids, the rate of transfer decreasing with an increase in the viscosity of the circulation fluid.								
10. The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure.								
11. Radiant energy travels in waves along straight lines, its intensity at any distance from a point is inversely proportional to the square of the distance from the source.								

	I	II	III	IV	V	VI	VII	VIII
12. The more nearly vertical the rays of radiant energy, the greater the number that will fall upon a given horizontal area, and the greater is the amount of energy that will be received by that area.								
13. The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature, the greater is the amount of energy radiated.								
14. Dark, rough, or unpolished surfaces absorb or radiate energy more effectively than light, smooth, or polished surfaces.								
15. Bodies of land heat up and cool off more rapidly and more readily than bodies of water.								
16. The atmosphere of the earth tends to prevent the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.								
17. Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.								
18. The amount of heat which a constant mass of liquid or solid acquired when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.								
19. Every pure liquid has its own specific boiling and freezing point.								
20. The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.								

	I	II	III	IV	V	VI	VII	VIII
21. Freezing point depression and boiling point elevation are proportional to the concentration of the solution								
22. The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.								
23. The rate of evaporation of a liquid varies with temperature, area of exposed surface, and saturation and circulation of the gas in contact with the liquid.								
24. The rate of vaporization decreases with an increase of concentration of the vapor in the gas in contact with the liquid, the temperature remaining constant.								
25. Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.								
26. When a gas expands, heat energy is converted into mechanical energy.								
27. The higher the temperature of the air, the greater the amount of moisture required to saturate it.								
28. The pressure of a saturated vapor is constant at a given temperature, and increases with an increase of temperature.								
29. Each combustible substance has a kindling temperature which varies with its condition, but may be greater or less than the kindling temperature of some other substance.								

APPENDIX D

SCIENCE EXAMINATION:

PART B BY HAROLD E. WISE

SCIENCE EXAMINATION

Part B

Compiled by

Harold E. Wise
University of Nebraska
Lincoln, Nebraska

Directions: DO NOT MARK THIS TEST BOOKLET IN ANY WAY. A special answer sheet and a special pencil have been provided. Answers are to be marked on the answer sheet using the special pencil.

Before beginning the test, fill in the blank spaces on the heading of the answer sheet as directed by your instructor. When this has been done, read the directions for answering the test items which are included as a part of the heading of the answer sheet and study the sample question which is given as a part of these directions. In the present test you are to select from the alternative responses for each item that one which you believe to be the best answer. In other words, you are to select for each item the answer which presents the most complete or most accurate statement and designate this answer on the answer sheet. Please answer all of the questions to the best of your ability.

---

1. The interior of a closed automobile becomes very warm if the car is allowed to stand for some time in bright sunshine on a cold winter day.

    1. The rays of sunlight are trapped in the car because the windows are closed.
    2. The closed windows not only keep the cold out but transmit heat from the sun to the interior of the car.
    3. Waves of radiant energy are transmitted by the glass and absorbed by the upholstering of the car.
    4. Heat from the motor comes back into the closed car and makes it warmer.

2. On a summer day the temperature in Washington, D. C., is 95 degrees Fahrenheit with a relative humidity of 90 percent. On the same day the temperature in Denver, Colorado, is also 95 degrees, but the relative humidity is only 25 percent. People in Washington will experience greater discomfort due to the heat because

    1. The altitude of Washington, D. C., is much lower than that of Denver.
    2. People in Denver will perspire more and will therefore feel cooler than people in Washington because heat is taken from the body as perspiration evaporates.

3. Perspiration will not evaporate as rapidly under conditions in Washington, D. C., as under conditions in Denver.
4. Due to its location near the mountains, there is usually considerable breeze during the day-time in Denver, Colorado.

3. The planet Mars is approximately one and one-half times more distant from the sun than is the earth. Other things being equal, we should therefore assume that the temperature of Mars is

1. only about two-thirds that of the earth.
2. less than one-third that of the earth.
3. slightly over one-half that of the earth.
4. less than one-half that of the earth.

4. The planet Mercury is located only about one-third as far away from the sun as is the earth. The quantity of heat from the sun received by Mercury should, therefore, be

1. three times greater than that received by the earth.
2. nine times greater than that received by the earth.
3. twenty-seven times greater than that received by the earth.
4. only one-third of that received by the earth.

5. Even in very cold weather snow covering a busy highway soon changes to ice. The reason is that

1. ice is nothing but closely packed snow.
2. heat produced by the friction of many wheels causes the snow to melt and the resulting water freezes into ice.
3. the melting point of ice is lowered by pressure.
4. the freezing point of ice is raised by pressure.

6. The buds on fruit trees usually will not freeze until the temperature drops two or three degrees below the freezing temperature for distilled water. The reason is that

1. the "sap" in the bud is protected from the weather by the bud scales.
2. the liquid in the bud is made up of a solution which freezes at a lower temperature than pure water.
3. distilled water freezes at a temperature somewhat above the freezing point of ordinary water.
4. freezing is somewhat retarded by radiation of heat from the dark colored portions of the tree.

7. The coolant in an automobile radiator must be protected from freezing because

1. the engine will not warm up enough to run efficiently if the liquid in the radiator is permitted to freeze.
2. the coolant must circulate through the engine and radiator otherwise the engine will overheat and be ruined.
3. the metal of the radiator and engine is likely to crack at temperatures near the freezing point of water.
4. the expansion which accompanies freezing is very likely to crack or burst the radiator or engine "block."

8. There is ample evidence of the fact that a glacier may "flow" or move steadily down a crooked valley. This is made possible by the fact that

1. ice expands as it melts.
2. pressure tends to lower the melting point of ice.
3. pressure tends to raise the melting point of ice.
4. a large quantity of ice behaves as a viscous substance.

9. An electric refrigerator is placed in a small room which is so insulated that heat energy can neither enter nor leave the room. During the time the refrigerator is in operation, the temperature of the air in the room will

1. increase steadily.
2. decrease continuously.
3. decrease, slowly at first and then more rapidly.
4. remain constant.

10. The rate of evaporation from the surface of water contained in an open beaker may be increased by

1. increasing the temperature of the water in the beaker.
2. decreasing the temperature of the water in the beaker.
3. increasing the degree of saturation of the air above the surface of the water.
4. decreasing the area of the exposed surface of the water.
5. retarding the circulation of air above the surface of the water.

11. A certain city in California is located on the shoreline of the Pacific Ocean which extends along its entire west side. One may therefore expect that

1. there will usually be a cool breeze blowing from the water to the land; that is, from west to east.
2. during each forenoon the direction of the wind will shift from the east to the west.

3. in late evening the direction of the wind will usually shift from the east to the west.
4. during each forenoon the direction of the wind will usually shift from the west to the east.

12. Benton Harbor, Michigan, is located on the east shore of Lake Michigan. As compared with a point exactly opposite Benton Harbor but on the west shore of the lake, one would expect that

1. spring would come earlier in Benton Harbor.
2. fall would come earlier in Benton Harbor.
3. there would be no noticeable difference in the time of arrival of either spring or fall.
4. both spring and fall would come later in Benton Harbor.

13. During the manufacturing process gold and silver coins must be "stamped" rather than "cast" because

1. gold and silver cannot be melted at temperatures ordinarily obtainable in manufacturing processes.
2. neither gold nor silver expands as it changes from the liquid to the solid state.
3. both gold and silver have high specific heats.
4. a substance suitable for use as a mold for casting gold and silver has not yet been discovered.

14. At 9 o'clock in the morning of a clear day in December, a young tree casts a shadow 14 feet long. At 9 o'clock in the morning of a clear day in June it would be expected that this tree would cast a shadow

1. less than 14 feet long.
2. exactly 14 feet long.
3. greater than 14 feet long.

15. Kerosene is sometimes used as an aid in starting a fire because it

1. has a relatively low kindling temperature.
2. burns with an intensely hot flame.
3. will burn brilliantly even in the absence of a supply of oxygen.
4. is an explosive substance but when used in small quantities will start a fire very quickly.

16. Other conditions being equal, automobile tires are more likely to "blow out" on a hot than a cold day. The reason is that:

1. the tensil strength of rubber decreases as the temperature is increased.
2. air contracts when it is heated and the tires are really under-inflated on a hot day.

3. air expands when heated and the pressure of air in an automobile tire therefore increases as the temperature increases.
4. increased temperature of the paving on a hot day causes excessive tire temperatures.

17. One must be careful not to touch a metal object with wet hands if the temperature is below freezing. This is due to the fact that:

1. the metal may conduct heat away from the hands so rapidly that the water will freeze and the hands will stick to the metal.
2. metal objects heat up and cool off very rapidly, and are therefore, usually colder than other objects.
3. since water is an excellent conductor of heat, the hands may freeze fast to the metal.

18. Some steam engines (called compound engines) have more than one cylinder and are so arranged that the steam leaving the first cylinder enters the second cylinder, then the third cylinder, etc. In such an engine the cylinders

1. are all equal in size.
2. vary in size and are so arranged that the steam always passes from a smaller to a larger cylinder.
3. vary in size and are so arranged that the steam always passes from a larger to a smaller cylinder.

19. Water is commonly used to put out fire because

1. when combustible materials are wet they will not burn.
2. water cuts off the supply of oxygen which is necessary for burning.
3. water absorbs large quantities of heat as it vaporizes thus lowering the temperature of the burning materials below the kindling temperature.
4. cold water absorbs large quantities of heat as its temperature increases thus lowering the temperature of the burning materials below the kindling temperature.

20. Much more rainfall occurrs on the west slope of the Pacific Coastal range of mountains than on the eastern slope. This is due to the fact that

1. temperatures along the west coast are higher than temperatures farther inland due to the Japanese Current in the Pacific.
2. warm moist air currents from the equator are deflected to the west by the mountains due to the rotation of the earth.
3. the west slope of the mountains is nearer to the source of the moisture which is the Pacific Ocean.
4. as winds from over the ocean blow toward the mountains, the moist air is lifted and cooled causing precipitation.

21. There is an increasing tendency for oil companies to use white or very light colored paint for gasoline and oil storage tanks which are exposed to the weather. The light colored paint is preferable for this purpose because:

1. it absorbs less heat from the sun and therefore reduces loss due to evaporation of the oil or gasoline and also reduces the danger of fire.
2. it makes the oil storage tanks inconspicuous when viewed from the air which would be very helpful in case of an air attack on a town or city.
3. in the presence of gasoline vapors it offers better protection for metals against rust and corrosion.

22. A glass flask containing a small amount of water is closed with a rubber stopper through which passes a glass tube. Air from a bicycle pump is pumped into the flask through rubber tube until the stopper "blows out." As the stopper "blows out," the space in the flask above the water is observed to be filled with fog. This fog is caused by:

1. small particles of water which are forced up into the top part of the flask as the stopper leaves the flask.
2. heating of the air in the flask as more and more air is forced into it by the bicycle pump.
3. condensation of water vapor due to sudden cooling of the air and vapor in the flask as the stopper leaves the flask.
4. excessive evaporation of water as the pressure on the surface of the water is suddenly decreased by the stopper leaving the flask.

23. As a thunderstorm approaches an observer, the direction of the wind as noted by the observer will most frequently be:

1. from the direction opposite to that from which the storm approaches.
2. from the observer's left as he faces the approaching storm.
3. from the observer's right as he faces the approaching storm.
4. from the same direction as that from which the storm approaches.

24. Dew is seldom observed on the surface of cement sidewalks on summer mornings. This is due to the fact that:

1. dew does not form on the sidewalks because the sidewalk does not cool enough during the night to permit its formation.
2. the dew evaporates from the surface of the sidewalk as fast as it forms.
3. the cement has a lower specific heat than the grass and ground surrounding the sidewalk.
4. dew can only form on the surface of green plants.

25. Relatively high barometric pressure in a given locality is usually associated with relatively

1. cool temperatures with high humidity.
2. warm temperatures with low humidity.
3. cool temperatures with low humidity.
4. warm temperatures with high humidity.

26. Structural steel workers acquire great skill in handling red hot rivets. Rivets used in the construction of tall buildings are usually inserted and "headed" while hot.

1. The rivets must be hot in order to be plastic enough to be "headed."
2. The rivets must be hot in order that they may be forced into position. regardless of irregularities in the "matching" of holes in the plates.
3. Hot rivets contract as they cool and insure a tight joint at all normal temperatures.
4. The rivets are heated in order to "temper" the steel of which they are made and make the rivet stronger.

27. In general, frost is less likely to occur on a cloudy night. This is because

1. clouds and moisture in the air blanket the surface of the earth and prevent rapid loss of heat by radiation.
2. water vapor gives up heat as it condenses to form clouds and this heat prevents the formation of frost.
3. frost cannot form if the relative humidity is near 100 percent.
4. when clouds are present, moisture in the air will condense on the drops of water which make up the clouds rather than upon objects on the earth's surface.

28. During the winter a person who wears glasses is frequently annoyed by a film of water collecting on his glasses when he enters a warm building from the out of doors. The formation of this film of water

1. will occur only when the relative humidity in the building is very low.
2. is caused by the sudden cooling of the layers of air in contact with the lenses of the glasses.
3. is caused by the fact that glass has a high specific heat and thus warms up quite slowly when one enters a warm room.
4. is caused by the sudden warming of the layer of air in contact with the lenses of the glasses.

29. All gases may be liquified by

1. increasing pressure and temperature.

2. decreasing pressure and increasing temperature.
3. decreasing pressure and temperature.
4. increasing pressure and decreasing temperature.

30. If equal weights of hot and cold water are mixed, the temperature of the mixture will be approximately halfway between the original temperatures. If a pound of iron at 200 degrees Fahrenheit is submerged in a pound of water at 100 degrees Fahrenheit, the final temperature of both the water and iron will be

1. 150 degrees Fahrenheit.
2. a few degrees above 100 degrees Fahrenheit.
3. a few degrees below 200 degrees Fahrenheit.

31. The so-called "permanent" types of antifreeze liquids are superior to alcohol for use in automobile radiators because they have

1. specific heats which are higher than that of alcohol.
2. heats of fusion which are lower than that of alcohol.
3. boiling points which are higher than that of alcohol.
4. surface tensions which are lower than that of alcohol.

32. A "sea breeze" is caused by the fact that

1. water heats up and cools off more rapidly than land.
2. warm air has a tendency to rise and thus permit cooler air to replace it next to the earth's surface.
3. cold air has a tendency to force warmer air upward and to displace it near the earth's surface.
4. heated air is more dense than cooler air.

33. If pure water at a temperature of 20 degrees Centigrade is placed in an open beaker and cooled steadily, its temperature will decrease

1. steadily until it reaches 4 degrees C. then much more slowly as freezing takes place.
2. steadily until it reaches 0 degrees C. after which it will remain constant as freezing takes place and then decrease steadily.
3. steadily until it reaches 0 degrees C. after which it will remain constant even after freezing is complete.
4. rapidly at first and then more slowly until finally it reaches 0 degrees C. and freezing begins.

34. In the northern hemisphere the average temperature on December 21 is considerably lower than that of June 21 because

1. the earth is nearer to the sun on June 21.
2. the sun radiates more heat during the summer months than during the winter months.

3. the days are longer in December than they are in June.
4. the rays of sunlight strike the earth at a greater angle in December than in June.

35. The force which results from an explosion of dynamite and similar explosives is due to

1. the chemical composition of the gases resulting from the explosion.
2. the compression of gases resulting from the explosion.
3. the intense heat produced by the explosion.
4. the sudden expansion of gases which is caused by the intense heat.

36. Either the "head" of a match or in the case of "safety matches," the surface against which the match is "struck" contains a compound of phosphorus. Phosphorus is used because it

1. burns brilliantly for only a short time.
2. has a relatively low kindling temperature.
3. is an oxidizing agent.
4. has a relatively high kindling temperature.
5. burns with a very hot flame.

37. In the Northern Hemisphere the earth absorbs less heat from the sun during December than during June because

1. the days are longer during December than during June.
2. the sun is closer to the earth during June than during December.
3. the rays of sunlight strike the earth more vertically during June than during December.
4. the atmosphere usually contains more moisture and more clouds during December than during June.

38. The ordinary whirlwind which is often observed in midwestern states during the spring is most likely to originate over

1. fields covered with growing crops.
2. fields covered by pools of water.
3. bare fields on which there is no growing vegetation.
4. fields covered by dead plant materials (the remains of last year's crops).

39. On a warm summer day the dry sand along the beach of a lake, river, or ocean becomes much warmer than the water. The reason is that

1. it requires more heat to change the temperature of a pound of water by one degree on the thermometer scale than it does to change the temperature of a pound of sand by one degree.
2. the surface of the water reflects more of the radiant heat from the sun than is reflected by the surface of the sand.

3. cooling caused by evaporation from the surface of the water keeps the temperature of the water below that of the sand.
4. sand looses heat at night much less rapidly than water thus during successive warm days the average temperature of the sand becomes greater than that of the water.

40. Heat from the sun may cause the inside of a closed automobile to become quite warm even though the outside temperature is relatively low. In such cases the temperature of the glass through which sunlight reaches the interior of the car will probably be

1. approximately the same temperature as the inside of the automobile.
2. approximately the same as the outside temperature.
3. about halfway between the outside temperature and the temperature on the inside of the car.

41. If a heated object is placed among but not in contact with surrounding objects which are at a lower temperature, it will loose heat to the surrounding objects by

1. radiation.
2. convection.
3. reflection.
4. conduction.

42. In the vapor vacuum type of steam heating system, the air is pumped out and kept out of the radiators' pipes and boiler. In such a system water will boil and produce steam

1. at temperatures above 212 degrees Fahrenheit.
2. at temperatures below 212 degrees Fahrenheit.
3. at 212 degrees Fahrenheit.
4. at either No. 1 or No. 3 above.

43. The principle basic to the efficient operation of the pressure cooker is that

1. water boils at a temperature higher than normal if the pressure on its surface is greater than atmospheric pressure.
2. water boils at a temperature higher than normal if the pressure on its surface is less than atmospheric pressure.
3. less heat is required to cook food in a partial vacuum because the cell structure of the food is more easily broken down.
4. heating food under pressure causes the heat to penetrate the food material much more efficiently thus decreasing the time required for thorough cooking.

44. Hot water evaporates more rapidly than cold water. The reason is that

1. steam is less dense than water.

2. the air immediately above the surface of hot water is less saturated than the air above the surface of colder water.
3. water contracts as it cools until it reaches a temperature of four degrees Centigrade then expands on further cooling until the freezing temperature is reached.
4. the average speed of the molecules of water increases as the temperature increases.

45. The temperature of the air in a football rises as it is inflated in proportion to the amount of air which is forced into it. The reason is that

1. air pressure increases as more and more air is forced into a given space.
2. the space within the football becomes more nearly filled with air molecules.
3. the average speed of the molecules of air within the football increases as more air is forced into the same space.
4. air on the inside of the football expands as it is heated by more air being forced into the same space.

46. Many mechanical devices make use of compressed air to accomplish useful work. In such devices

1. some heat is always produced as the compressed air is permitted to expand and do work.
2. the compressed air must always be at a pressure of at least two atmospheres if it is to do useful work at atmospheric pressure.
3. if the compressed air is permitted to expand in doing useful work its temperature will be lowered.
4. the air pressure is always maintained at 14.7 pounds per square inch.

47. Other things being equal, vegetables will cook more rapidly in boiling salt water than in boiling fresh water. The reason is that

1. the salt water promotes more rapid osmosis through the skin of the vegetables.
2. salt water is a better conductor of heat than fresh water.
3. unlike fresh water, the temperature of the salt water continues to rise after boiling begins.
4. the boiling point of salt water is higher than that of fresh water.

48. The cooling coils of a mechanical refrigerator must be "defrosted" occasionally if the refrigerator is to continue to operate efficiently. Removal of the "frost" or ice is necessary because

1. ice is not as good a conductor of heat as is the metal of the cooling coils.

2. it costs more to operate the refrigerator if the ice on the coils is allowed to accumulate.
3. the internal temperature of the refrigerator cannot drop below the temperature of melting ice until all of the ice is removed from the coils.
4. ice on the cooling coils retards the transmission of heat from the coils to the food in the refrigerator.

APPENDIX E

MECHANICS PRINCIPLES -

MECHANICS EXPERIMENTS RATING SHEET

MECHANICS EXPERIMENT RATING SHEET

NAME ____________________ DATE __________

POSITION __________ INSTITUTION __________

- -

Instructions: In each block beside the principles assign each experiment one of the following numerical values, viz.:

0 - if the experiment <u>does not</u> illustrate the principle.
1 - if the experiment illustrates the principle only <u>partially</u> or <u>poorly</u>.
2 - if the experiment illustrates the principle <u>fairly well</u>.
3 - if the experiment illustrates the principle <u>very well</u>.
4.- if the experiment illustrates the principle <u>ideally</u>.

MECHANICS EXPERIMENTS	MECHANICS EXPERIMENT I Work & Power: Stair-step exp.	MECHANICS EXPERIMENT II Inclined Plane. Friction. Principle of Work.	MECHANICS EXPERIMENT III Simple Machines; M.A. & M.E.	MECHANICS EXPERIMENT IV Concurrent Forces	MECHANICS EXPERIMENT V Mechanical Equivalent of Heat--Joule's Law
MECHANICS PRINCIPLES					
1. Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.					
2. Movements of all bodies in the solar system are due to gravitational attraction and inertia.					
3. The speed gained by a body with constant acceleration is equal to the product of the acceleration and the time.					
4. The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.					

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V
5. The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force.					
6. At any point on the earth's surface all bodies fall with a constant acceleration, which is independent of the mass or size of the body if air resistance be neglected.					
7. The amount of momentum possessed by an object is proportional to its mass and to its velocity.					
8. When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.					
9. Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.					
10. The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.					
11. The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.					
12. The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.					
13. When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.					
14. In the lever, the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.					

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V
15. In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.					
16. Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together, and independent of area of contact.					
17. The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.					

APPENDIX F

ELECTRICAL PRINCIPLES -

ELECTRICAL EXPERIMENTS RATING SHEET

ELECTRICAL PRINCIPLES -- EXPERIMENTS RATING SHEET

NAME ______________________

ADDRESS ____________________

DATE ______________________

- -

<u>DIRECTIONS</u>: Please rate the experiments as they illustrate the principles of electricity and magnetism listed below according to the following rating system.

0 - if the experiment <u>does</u> <u>not</u> illustrate the principle.
1 - if the experiment illustrates the principle only <u>partially</u> or <u>poorly</u>.
2 - if the experiment illustrates the principle <u>fairly</u> <u>well</u>.
3 - if the experiment illustrates the principle <u>very</u> <u>well</u>.
4 - if the experiment illustrates the principle <u>ideally</u>.

ELECTRICAL PRINCIPLES	ELECTRICAL EXPERIMENT I ELECTRICAL APPLIANCES & THE ELECTRIC BILL	ELECTRICAL EXPERIMENT II LAWS OF ELECTRICAL RESISTANCE	ELECTRICAL EXPERIMENT III TWO FILMS ON ELECTRICITY 1. THE ELECTRON 2. ELECTRODYNAMICS	ELECTRICAL EXPERIMENT IV THE ELECTRIC BATTERY CELL	ELECTRICAL EXPERIMENT V MAGNETIC FIELDS			
1. Pieces of iron, steel, cobalt, or nickel may become magnetized by induction when placed within a magnetic field.								
2. A magnet always has two poles and is surrounded by a field of force.								

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII	EXP.VIII
3. Like magnetic poles always repel each other and unlike magnetic poles always attract each other.								
4. The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.								
5. Magnets depend for their properties upon the arrangement of the individual atoms or molecules of which they are made up.								
6. Moving electrons have both a magnetic and an electric field.								
7. Like electrical charges repel and unlike electrical charges attract.								
8. In an uncharged body there are as many protons as electrons and the charges neutralize each other; while a deficiency of electrons produces a plus charge on a body and an excess of electrons produces a negative charge.								
9. The force of attraction or repulsion between two small charged bodies varies directly as the product of the two charges and inversely as the square of the distance between the charges.								

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII	EXP.VIII
10. Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.								
11. Charges on a conductor tend to stay on the surface and to be greatest on the sharp edges and points.								
12. An electric current may be produced in four ways: by rubbing or friction, by chemical action, by the use of conductors cutting magnetic fields.								
13. An electric current will flow in the external circuit, when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.								
14. Gases conduct electric currents only when ionized.								
15. Electrical power is directly proportional to the product of the potential difference and the current.								
16. The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.								

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII	EXP.VIII
17. All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.								
18. The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with length, inversely with the cross-sectional area.								
19. In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the same for each branch, and the total resistance is less than the resistance of any one branch.								
20. In a series circuit the current is the same in all parts, the resistance of the whole is the sum of the resistance of the parts, and the voltage loss of the whole is the sum of the voltage losses of the parts.								
21. An electrical charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.								

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII	EXP.III
22. When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.								
23. In a transformer the ratio between voltages in the primary and secondary circuits is the same as that between the number of turns of wire in these circuits.								
24. The amount of heat produced by an electric current is proportional to the resistance, the square of the current and the time of flow.								
25. Energy in kilowatt hours is equal to the product of amperes, volts and time(in hours), divided by one thousand.								
26. An e.m.f. is induced in a circuit whenever there is a change in the number of lines of magnetic force passing through the circuit.								
27. An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current was produced.								
28. The magnitude of an induced e.m.f. is proportional to the rate at which the number of lines of magnetic force change and to the number of turns of wire in the coil.								

APPENDIX G

WAVE PHENOMENA PRINCIPLES -

WAVE PHENOMENA EXPERIMENTS RATING SHEET

WAVE PHENOMENA PRINCIPLES--WAVE PHENOMENA EXPERIMENT RATING SHEET

NAME____________________ DATE__________

POSITION__________ INSTITUTION_______

- -

Instructions: In each block beside the principles assign each experiment one of the following numerical values, viz.:

0 - if the experiment does not illustrate the principle.
1 - if the experiment illustrates the principle only partially or poorly.
2 - if the experiment illustrates the principle fairly well.
3 - if the experiment illustrates the principle very well.
4 - if the experiment illustrates the principle ideally.

WAVE PHENOMENA EXPERIMENTS	WAVE EXPERIMENT I Sound: Wavelength and Velocity	WAVE EXPERIMENT II Sound: Vibration Rate of a Tuning Fork	WAVE EXPERIMENT III Sound: Vibrating Strings	WAVE EXPERIMENT IV Light: The Photometer	WAVE EXPERIMENT V Light: The Law of Reflection	WAVE EXPERIMENT VI Light: Images in a Plane Mirror	WAVE EXPERIMENT VII Light: Images in Curved Mirrors
WAVE PHENOMENA PRINCIPLES							
1. Energy is often transmitted in the form of waves.							
2. Waves travel in straight lines while passing through a homogeneous medium.							
3. When waves strike an object, they may either be absorbed, transmitted, or reflected.							

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII
4. Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object.							
5. The darker the color of a surface, the better it absorbs light.							
6. If a beam of light falls on an irregular surface, the rays of light are scattered in all directions.							
7. When light is reflected, the angle of incidence is equal to the angle of reflection.							
8. When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.							
9. The dispersion of white light into a spectrum by a prism is caused by unequal refraction of different wavelengths of light.							
10. Parallel light rays may be converged or focused by convex lenses or concave mirrors diverged by concave lenses or convex mirrors.							
11. Incandescent solids and liquids emit all wavelengths of light and give a continuous spectrum.							
12. Luminous vapors and gases emit only certain kinds of light producing bright line spectra.							

	EXP.I	EXP.II	EXP.III	EXP.IV	EXP.V	EXP.VI	EXP.VII
13. When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wavelength end of the spectrum respectively.							
14. A beam of light may become plane polarized as the result of any circumstance which results in the suppression of the rectilinear components of the vibration without affecting the components at right angles to it.							
15. Sound is produced by vibrating matter and is transmitted by matter.							
16. When energy is transmitted in waves, the medium which transmits the wave motion does not move along with the wave, but the energy does.							
17. Each vibrating particle in a wave front of any wave motion may be considered as a secondary source of spherical wavelets which spread out from their source with the velocity of the primary wave.							
18. The speed of sound increases with an increase in the temperature of the medium conducting it.							
19. The velocity of a wave is equal to the product of its frequency and wavelength.							
20. Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.							

	EXP. I	EXP. II	EXP. III	EXP. IV	EXP. V	EXP. VI	EXP. VII
21. Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.							
22. The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.							
23. The higher the pitch of a note, the more rapid the vibrations of the producing body.							
24. When a sounding body is moving toward or away from an observer, the apparent pitch will be higher or lower respectively, than the true pitch of the sound emitted.							
25. Two sound waves of the same frequency or of nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rarefactions of the other provided that the directions of the propagation are the same.							
26. Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly timed to correspond to any of the natural periods of vibration of the body.							

APPENDIX H

MECHANICS EXAMINATION

MECHANICS EXAMINATION

Directions: Give the number of the word, number, or phrase which best completes or answers each of the following statements.

1. Rocket propulsion is an application of Newton's (1) first law; (2) second law; (3) third law; (4) first and third laws.

2. A uniformly accelerated ball starts from rest and rolls 2 ft. during the first second. Its acceleration is (1) 2 ft/sec; (2) 2 ft/sec^2; (3) 4 ft/sec^2; (4) 32 ft/sec^2.

3. If the acceleration of an object is uniform the distance it travels in any given number of seconds equals (1) at; (2) $\frac{1}{2}at^2$; (3) $\sqrt{2as}$ (4) $\frac{1}{2}a(2t-1)$.

4. The stopping of an automobile is an example of (1) acceleration; (2) deceleration; (3) accelerated motion; (4) decelerated motion.

5. The relationship between force and mass is given by the (1) first law of motion; (2) second law of motion; (3) third law of motion; (4) first and third laws of motion.

6. If the distance between two bodies is doubled, the attraction between them (1) is reduced to one-fourth; (2) is reduced to one-half; (3) is doubled; (4) is four times as great.

7. The CGS unit of kinetic energy is the (1) erg; (2) dyne; (3) watt; (4) erg/sec.

8. The unit of work in the FPS system is (1) joule; (2) erg; (3) dyne; (4) ft-lb.

9. One joule equals (1) 100 ergs; (2) 10,000 dynes; (3) 10,000,000 ergs; (4) 10,000,000 watts.

10. Energy is measured in the same units as (1) power; (2) work; (3) momentum; (4) inertia.

11. A nail if an example of (1) an inclined plane; (2) a lever; (3) a screw; (4) wedge.

12. A dyne is a unit for measuring (1) speed; (2) acceleration; (3) gravity; (4) force; (5) work.

13. Rate of change of velocity is called (1) speed; (2) acceleration; (3) momentum; (4) terminal velocity; (5) impulse.

14. A plank 12 ft. long is balanced on a support placed under the center of the plank. A 60-lb. weight placed 5 ft. from the support can be balanced by a 75-lb. weight placed at a distance from the support of (1) 3 ft; (2) 4 ft.; (3) 5 ft.; (4) 64 ft.

15. The acceleration of a freely falling body is (1) 32 cm. per sec. per sec. (2) 32 ft. per sec. (3) 980 cm. per sec. (4) 9.8 m. per sec. per sec.

16. Energy may be measured in (1) foot-pounds; (2) kilograms; (3) dynes; (4) pounds; (5) horsepower.

17. The output of a machine is (1) the product of applied effort and distance; (2) always more than the input; (3) measured in work units; (4) the same as efficiency.

18. By the expenditure of 450 g.-cm. of work a 90-gram weight can be raised to a height of (1) 5 cm.; (2) 50 cm.; (3) 540 cm.; (4) 4,050 cm.; (5) 40,500 cm.

19. When work has been done on a body, it is said to have more (1) momentum; (2) mechanical advantage; (3) energy; (4) horsepower.

20. The mechanical advantage of a screw may be increased by (1) increasing the applied force; (2) increasing the number of threads per inch; (3) increasing the pitch; (4) decreasing the length of the handle.

21. The mechanical advantage of a machine is (1) always attained by a sacrifice of speed; (2) the same as efficiency; (3) the ratio of the force overcome on it to the force exerted; (4) the work done on the machine.

22. The screw is a modified form of the (1) lever; (2) pulley; (3) inclined plane; (4) gear; (5) wheel and axle.

23. The kinetic energy of a body varies (1) inversely as the velocity; (2) inversely as its mass; (3) directly as the distance moved; (4) directly as the square of the velocity; (5) directly as the product of mass and velocity.

24. Mechanical advantage is the ratio of (1) effort to resistance; (2) resistance to effort; (3) output to input; (4) work accomplished to work put in.

25. A force of 60 lb. raises a load of 150 lb. to a height of 25 ft. in 5 sec. The work accomplished is (1) 150 ft.-lb.; (2) 150 x 25 ft-lb.; (3) $\frac{60 \times 25}{5}$; (4) $\frac{150 \times 25}{5}$; (5) 60 x 25.

26. A body falling freely through the air (1) gains energy; (2) has kinetic energy only; (3) has both kinetic and potential energy; (4) loses kinetic energy.

27. You are standing in a moving train. The train stops suddenly and you fall forward. This illustrated (1) the Law of Gravitation; (2) Newton's First Law of Motion; (3) Newton's Third Law of Motion; (4) centripetal force.

28. The Law of Gravitation was formulated by (1) Pascal; (2) Boyle; (3) Newton; (4) Galileo.

29. Acceleration is the (1) speed of a body; (2) change in the speed; (3) reaction of a force; (4) rate of change of the speed.

30. In the first second a freely falling body falls a distance of (1) 8 ft.; (2) 16 ft.; (3) 32 ft.; (4) 64 ft.

31. All bodies have (1) momentum; (2) inertia; (3) velocity; (4) uniform acceleration.

32. An absolute unit of force is the (1) gram; (2) pound; (3) dyne; (4) erg; (5) kilogram.

33. A train has more momentum than an automobile traveling at the same speed because the train (1) has greater velocity; (2) has greater mass; (3) is streamlined; (4) has more acceleration; (5) has a larger moment.

34. Efficiency of a machine (1) is the ratio of the input to the output; (2) is always less than 100%; (3) is not affected by friction; (4) decreases if the applied effort decreases.

35. The amount of work done in a unit time is a measure of (1) momentum; (2) force; (3) power; (4) energy; (5) mechanical advantage.

36. A 10-horsepower engine can do work at the rate of (1) 550 ft.-lb. per min.; (2) 5,500 ft.-lb. per min.; (3) 3,300 ft.-lb. per min.; (4) 330,000 ft.-lb. per min.; (5) 330,000 ft.-lb. per hr.

37. Increasing the length of an inclined plane increases the (1) mechanical advantage; (2) efficiency; (3) force needed to slide a box up the plane; (4) work accomplished.

38. Power is given by the relation (1) force x $(\text{velocity})^2$; (2) force x distance; (3) weight x distance; (4) weight x height; (5) $\frac{\text{force x distance}}{\text{time}}$.

39. The wheel and axle is a modified form of the (1) lever; (2) screw; (3) pulley; (4) inclined plane.

40. Watt is a unit of (1) work; (2) light; (3) power; (4) energy; (5) force.

41. Work is done (1) when you hold a book in your hand; (2) when you push against the wall; (3) when a ball is suspended from the ceiling; (4) when you write.

42. Machines are used to (1) create energy; (2) multiply force; (3) accomplish more work; (4) increase efficiency.

43. The ability to do work is called (1) energy; (2) mechanical advantage; (3) efficiency; (4) horsepower.

44. The mechanical advantage of a lever may be increased by (1) increasing the input of work; (2) increasing the length of the resistance arm; (3) increasing the length of the effort arm; (4) increasing the length of both arms equal amounts.

45. Whenever work is done, there is a transfer of (1) power; (2) heat; (3) matter; (4) energy; (5) molecules.

46. The three general laws of motion were first formulated by (1) Archimedes; (2) Galileo; (3) Newton; (4) Aristotle.

47. A lead ball is dropped from a point 10 feet above the earth. At the same time an iron ball is started from the same point in a horizontal direction with a velocity of 10 feet per second. The time required for the lead ball to reach the earth is (1) the same as; (2) less than; (3) greater than that required for the iron ball to reach the earth.

48. A boy, inside of a car of a train moving with a uniform speed, throws a baseball vertically upward toward the roof of the car. When this ball comes down it will strike the floor (1) just below where it was thrown upward; (2) at a point toward the rear of the car from where it was thrown; (3) at a point toward the front of the car from where it was thrown.

49. The acceleration due to gravity at the North Pole is (1) equal to; (2) less than; (3) more than that at the same elevation at the equator.

50. The useful work done by a machine divided by the work done on the machine is called its (1) efficiency; (2) mechanical advantage; (3) power; (4) energy.

APPENDIX I

HEAT EXAMINATION

HEAT EXAMINATION

1. A liquid other than mercury which is used in thermometers is (1) alcohol; (2) water; (3) kerosene; (4) turpentine.

2. The relationship between mechanical energy and heat was determined quantitatively by (1) Joule; (2) Celsius; (3) Charles; (4) Rumford.

3. The two fixed points commonly selected for graduating a thermometer are (1) the boiling point of water and the boiling point of alcohol; (2) freezing point of water and the freezing point of mercury; (3) the freezing point of mercury and the boiling point of alcohol; (4) the boiling point of water and the melting point of ice.

4. A temperature of 243°K equals (1) 243°C; (2) 30°C; (3) -30°C; (4) -300°.

5. If a bimetallic strip of brass and iron is heated, it will (1) curve toward the brass; (2) remain straight; (3) curve toward the iron; (4) curve in an S-shape.

6. The increase in unit length of a solid when its temperature is increased one degree is called its (1) thermal coefficient; (2) coefficient of volume expansion; (3) coefficient of expansion; (4) coefficient of linear expansion.

7. Rivets form tight joints because (1) they are hammered in place tightly; (2) they fit the holes in the pieces of metal they join; (3) they are of stronger metal than the pieces they join; (4) they contract on cooling.

8. One Fahrenheit degree equals (1) one Centigrade degree; (2) 0.55 C°; (3) 1.8 C°; (4) -17.2°C.

9. A metal ball will just pass through a metal ring of the same material at room temperature. Under which of the following conditions will the ball <u>not</u> pass through the ring? (1) The ball and ring are both heated to 350°C; (2) the ring is heated to 350°C while the ball remains at room temperature; (3) the ball is heated to 350°C while the ring remains at room temperature; (4) the ball is at 0°C and the ring is at 100°C.

10. When a substance absorbs heat, (1) a chemical change occurs; (2) the volume may increase; (3) the substance changes to a vapor; (4) the substance becomes warmer.

11. When water is cooled from 100°C to 0°C, it (1) contracts and then expands; (2) expands and then contracts; (3) expands; (4) contracts.

12. The temperature at which fusion occurs is the (1) boiling point; (2) fixed point; (3) freezing point; (4) melting point.

13. The changine of molecules of liquid into molecules of vapor at such a rate that the liquid becomes agitated is called (1) evaporation; (2) boiling; (3) vaporization; (4) sublimation.

14. Moth balls have an odor because at room temperature they (1) sublime; (2) evaporate; (3) vaporize; (4) melt.

15. The amount of water vapor in one cubic foot of air is called (1) humidity; (2) capacity; (3) absolute humidity; (4) relative humidity.

16. The heat of vaporization of water at its normal boiling point is (1) 970 Btu/g; (2) 540 Btu/lb; (3) 540 cal/g; (4) 970 cal/lb.

17. Heat is measured by (1) a thermometer; (2) a thermostat; (3) a thermograph; (4) the effects it produces.

18. The more rapid evaporation of water on a day when the relative humidity is low shows that the rate of vaporization depends upon (1) the temperature; (2) the air pressure above the liquid; (3) the air movement above the liquid; (4) the amount of water in the air.

19. In order to convert 10 g. of ice at $0^{o}C$ to 10 g. of water at $0^{o}C$, we must (1) add 800 cal; (2) take away 800 cal; (3) add 80 cal; (4) add 800 Btu.

20. The amount of heat required to convert 1 g. of water at $50^{o}C$ into 1 g. of steam at $110^{o}C$ is (1) 600 cal; (2) 595 cal; (3) 590 cal; (4) 540 cal.

21. If the temperature of moist air is raised (1) the dew point remains the same; (2) the dry-bulb thermometer reading drops; (3) the relative humidity rises; (4) the capacity remains the same.

22. The amount of heat lost by 2 lb of metal, specific heat 0.1 Btu/lb F^{o}, in cooling from $170^{o}F$ to $70^{o}F$ is (1) 20; (2) 20 Btu; (3) 20 cal; (4) 0.2 k-cal.

23. The transfer of heat by moving currents of molecules is called (1) conduction; (2) convection; (3) radiation; (4) wind.

24. Cooking utensils are usually made of metals because metals (1) have a high specific heat; (2) have a low coefficient of expansion; (3) have a high melting point; (4) are good conductors of heat.

25. A material which is to reflect heat waves should be (1) smooth and light-colored; (2) smooth and dark-colored; (3) rough and light-colored; (4) rough and dark-colored.

26. The most comfortable relative humidity for conditioned air is (1) 20% to 40%; (2) 30% to 50%; (3) 40% to 60%; (4) 50% to 70%.

27. The vacuum between the walls of a vacuum bottle prevents heat transfer by (1) conduction; (2) conduction and convection: (3) convection; (4) radiation.

28. A pot holder is used to remove a hot iron frying pan from the stove because it prevents heat transfer to your hand by (1) conduction; (2) convection; (3) radiation; (4) conduction and convection.

29. Gases are poor conductors of heat because (1) gas molecules move rapidly; (2) gas molecules are far apart; (3) gas molecules do not collide very frequently; (4) gases have a low density.

30. In the northern hemisphere the trade winds blow from the (1) northeast; (2) northwest; (3) southeast; (4) southwest.

31. Conduction of heat in a body will take place (1) if all parts of the body are the same temperature; (2) from the part at higher temperature to the part at lower temperature; '3) from the part at lower temperature to the part at higher temperature; (4) from any one part to any other part.

32. The mechanical equivalent of heat is (1) 4.19 joules; (2) 4.19 ergs; (3) 4.19×10^7 joules; (4) joules/cal.

33. Heat transfer from a radiator to a hand placed beside it, but not touching it, is by (1) radiation; (2) conduction; (3) convection and conduction; (4) radiation and convection.

APPENDIX J

ELECTRICITY AND MAGNETISM EXAMINATION

ELECTRICITY AND MAGNETISM EXAMINATION

1. Magnetite is a material which is (1) a temporary magnet; (2) an artificial magnet; (3) a natural magnet; (4) a diamagnetic material.

2. A permanent magnet (1) retains its magnetism; (2) is easy to magnetize; (3) has low residual magnetism; (4) has little retentivity.

3. A material which is <u>not</u> magnetic is (1) iron; (2) cobalt; (3) copper; (4) nickel.

4. The space about a magnet is called (1) a magnetic line; (2) a magnetic field; (3) a line of force; (4) induced magnetism.

5. Repulsion occurs when (1) the N-pole of one magnet is brought near the S-pole of a second magnet; (2) the S-pole of one magnet is brought near the N-pole of a second magnet; (3) the N-pole of one magnet is brought near an unmagnetized piece of iron; (4) the S-pole of one magnet is brought near the S-pole of a second magnet.

6. If the head of a nail is brought in contact with the S-pole of a permanent magnet, (1) the head and point of the nail become S-poles; (2) the head of the nail becomes a N-pole; (3) the head of the nail becomes a S-pole; (4) the point of the nail becomes a N-pole.

7. If a darning needle is stroked from eye to point with the south pole of a magnet, (1) both the eye and the point become south poles; (2) the eye becomes a south pole; (3) the point becomes a south pole; (4) the eye becomes a north pole.

8. The force of attraction between magnets is (1) directly proportional to their distance apart; (2) inversely proportional to their distance apart; (3) directly proportional to the square of their distance apart; (4) inversely proportional to the square of their distance apart.

9. Static electric charges may be detected by using (1) an electrophorus; (2) a conical silk bag; (3) an electroscope; (4) a capacitor.

10. Which of these four does not belong with the other three? (1) Wool; (2) paraffin; (3) mica; (4) copper.

11. The intensity of charge on a charged conductor is greatest (1) on a flat surface; (2) on a gently curving surface; (3) on a sharply curving surface; (4) at a point.

12. If a charged hard-rubber rod is brought near a suspended neutral pith ball, the ball is (1) attracted and then repelled; (2) attracted; (3) repelled; (4) repelled and then attracted.

13. The movement of the pith ball in the preceding question is explained by the fact that it is charged (1) by induction; (2) by contact; (3) by contact and then by induction; (4) by induction and then by contact.

14. An electric charge (1) spreads uniformly throughout an object; (2) spreads over the outside of an object; (3) is found inside an object; (4) is found near one end of an object.

15. A hard-rubber rod becomes charged because it (1) rubs protons off the catskin; (2) rubs electrons off the catskin; (3) loses electrons to the catskin; (4) loses protons to the catskin.

16. If we liken the flow of electricity to the flow of water, the drops of water which make up the water stream represent (1) an electric current; (2) atoms; (3) electrons; (4) protons.

17. An example of a source of electromotive force is (1) a dry cell; (2) a Leyden jar; (3) an electroscope; (4) a capacitor.

18. The ohm is the unit of (1) potential difference; (2) current strength; (3) emf; (4) resistance.

19. In a direct current circuit powered by a dry cell in the circuit outside the cell (1) electrons flow toward the negative terminal; (2) electrons flow away from the negative terminal; (3) protons flow toward the negative terminal; (4) protons flow away from the negative terminal.

20. The characteristic of an electric circuit which is like difference in level in a hydraulic circuit is measured in (1) volts; (2) watts; (3) amperes; (4) ohms.

21. Ohm's Law may be stated algebraically as (1) $R = I/E$; (2) $I = RE$; (3) $E = I/R$; (4) $E = IR$.

22. The core of an electromagnet is made from (1) copper; (2) wood; (3) soft iron; (4) aluminum.

23. The potential difference across a resistance is 10 volts. If the current strength is 5 amperes, the power supplied is (1) 2 watts; (2) 3 watts; (3) 5 watts; (4) 50 watts.

24. A telephone receiver converts (1) electricity into sound; (2) magnetism into sound; (3) electricity to magnetism to mechanical energy to sound; (4) electricity to magnetism to sound.

25. The amount of heat produced in a conductor does <u>not</u> depend on (1) the resistance; (2) the current; (3) the time; (4) the amount of insulation.

26. An electric motor transforms (1) electromagnetism into mechanical energy; (2) magnetism into electromagnetism; (3) electricity into magnetic attraction; (4) electrical energy into mechanical energy.

27. It is not definitely known whether a piece of iron is magnetized or not. To test for magnetism, the piece of iron is brought up to the north end of a suspended magnet and it is found that the north pole of the magnet is repelled. This proves that (1) the piece of iron is magnetized, (2) the piece of iron is not magnetized, or (3) we do not have sufficient information to determine whether iron is magnetized or not.

28. An electroscope is charged negatively. A piece of material which is thought to be charged is brought near the knob of the electroscope and it is observed that the leaves diverge still farther. This shows that the material is (1) positively charged; (2) negatively charged; (3) uncharged; (4) or we do not have enough information to tell whether the material is charged or not.

29. At 6 cents a kilowatt-hour, the cost in cents of operating a 50-watt lamp for 100 hours is ___________.

30. An electric iron requires 5 amperes from a 110-volt line. At 6 cents a kilowatt-hour, the cost in cents of operating this iron continuously for 5 hours is (to one decimal place) ___________.

31. If the north-seeking pole of a compass needle is deflected to the east by electrons flowing through a conductor, the electrons are flowing (1) from south to north above the needle; (2) from south to north below the needle; (3) from north to south above the needle; (4) from east to west above the needle.

32. Which of the following methods cannot be used to demagnetize a magnet? (1) pounding; (2) direct current; (3) alternating current; (4) heating.

33. Which of the following is not correct? Magnetic lines of induction (or magnetic lines of force) (1) are considered to come out of the S-pole and to enter the N-pole; (2) are considered to come out of the N-pole and to enter the S-pole; (3) may be used to explain attraction of unlike magnetic poles and repulsion of like magnetic poles; (4) are more numerous the stronger the magnet.

APPENDIX K

WAVE PHENOMENA EXAMINATION

WAVE PHENOMENA EXAMINATION

Directions Give the letter of the word, number, or phrase which best completes or answers each of the following statements.

1. The number of waves passing a given point per second is the (a) amplitude; (b) period; (c) wave length; (d) intensity; (e) frequency.

2. The change in pitch observed as a sounding whistle passes you is an example of the principle of (a) Newton; (b) Maxwell; (c) Doppler; (d) Hertz; (e) Edison.

3. Sound is the type of wave known as (a) transverse; (b) longitudinal; (c) rotational; (d) pure sine; (e) tidal.

4. Objects that give off light of their own are said to be (a) illuminated; (b) luminous; (c) translucent; (d) transparent; (e) opaque.

5. A body appears black if the light rays which are incident upon it (a) are equally reflected; (b) are equally absorbed; (c) are refracted; (d) are all dispersed; (e) are of the same intensity.

6. The type of lens used to correct a nearsighted eye is (a) planoconvex; (b) double convex; (c) diverging; (d) converging; (e) dispersing.

7. The color of light depends on its (a) intensity; (b) speed; (c) wave length; (d) index of refraction; (e) amplitude.

8. A lens which is thinner in the middle than at the edges is (a) convex; (b) planoconvex; (c) plane; (d) diverging; (e) converging.

9. When a beam of light passes through a prism the color which is refracted most is (a) violet; (b) red; (c) green; (d) yellow; (e) blue.

10. A convex lens is one which (a) diverges the light; (b) is thicker in the middle than at the edges; (c) converges the light; (d) is opaque; (e) disperses the light.

11. A tuning fork vibrating over a cylinder partially filled with water is a means of determining which of the following for sound in air (a) intensity; (b) timbre; (c) velocity; (d) quality; (e) amplitude.

12. The term used in connection with sound which corresponds to color with reference to light is (a) pitch; (b) timbre; (c) tone; (d) intensity; (e) harmony.

13. Change in which of the following factors has the greatest effect on the velocity of sound in air? (a) temperature of the air; (b) atmosphere's pressure near earth's surface; (c) loudness of the sound; (d) energy associated with the sound wave; (e) the pitch or frequency of the sound.

14. When plane water waves pass through a small opening in a breakwater, the waves going through become curved about the opening as a center because of (a) reflection; (b) refraction; (c) diffraction; (d) interference; (e) Doppler effect.

15. Sound differs from light chiefly in (a) not being subject to diffraction; (b) that it is compressional wave rather than a longitudinal wave; (c) that it does not require energy for its origin; (d) that it is a longitudinal wave instead of a transverse wave; (e) that it lacks amplitude.

16. Light differs from sound chiefly in that it (a) does not obey the formula of V = wave length times frequency; (b) does not require a material medium for its transmission; (c) is not reflected; (d) does not contain energy; (e) is not a wave phenomena.

17. An open tube will be in resonance for a sound whose wave length is 3 feet if the tube has a length of (a) $\frac{1}{2}$ ft.; (b) $\frac{3}{4}$ ft.; (c) $1\frac{1}{2}$ ft.; (d) 4 ft.; (e) 6 ft.

18. The length of an air column determines its (a) quality; (b) loudness; (c) natural period of vibration; (d) amplitude; (e) velocity.

19. Beats are the result of (a) reflection; (b) refraction; (c) resonance; (d) interference; (e) diffraction.

20. A prism bends (a) red light more than green light; (b) red light more than infra-red light; (c) green light more than violet light; (d) violet light more than red light; (e) X-rays more than blue light.

21. Light of a single wave length cannot be (a) absorbed; (b) dispersed; (c) reflected; (d) refracted; (e) re-enforced.

22. Two nearby tuning forks, having vibration rates of 256 and 260 vibrations per second. When sounded simultaneously, the number of beats produced is (a) 256; (b) 260; (c) 4; (d) 16; (e) 2.

23. Increasing the amplitude of a sound wave increases its (a) pitch; (b) velocity; (c) loudness; (d) wave length; (e) frequency.

24. One can distinguish whether "c" (256 vibrations) is sounded on a piano or on a saxophone because they differ in (a) wave length; (b) amplitude; (c) fundamentals; (d) overtones; (e) velocity.

25. Sound is not transmitted by (a) air; (b) steel; (c) water; (d) steam; (e) a vacuum.

26. Sound travels fastest in (a) air; (b) steel; (c) water; (d) steam; (e) a vacuum.

27. Loudness in sound corresponds in light to (a) color; (b) Doppler effect; (c) brightness; (d) frequency; (e) timbre.

28. We see the majority of objects about us because (a) they emit light; (b) they reflect light; (c) they absorb light; (d) they are close to us; (e) light travels in straight lines.

29. By raising or lowering the water level in a cylinder above which is a vibrating tuning fork, points are located which are louder than the tuning fork alone. These points illustrate (a) quality; (b) resonance; (c) velocity; (d) noise; (e) music.

30. In the laboratory experiment referred to in item 29, the velocity of sound in air is obtained for (a) the existing room temperature; (b) the frequency of the tuning fork; (c) the loudness of the sound source; (d) the particular wave length used; (e) the column of water in the tube.

31. As light passes obliquely from a rarer to a denser medium it is always (a) absorbed; (b) refracted toward the normal; (c) refracted away from the normal; (d) reflected; (e) diffused.

32. When a ray of light strikes an optically smooth surface, that part of the ray which does not penetrate into the new medium behaves in such a way that the angle of incidence is equal to (a) a straight angle; (b) a right angle; (c) the critical angle; (d) the normal; (e) the angle of reflection.

33. If λ represents the length of a sound wave, the length of an air column which will produce resonance is (a) 1λ; (b) $\frac{1}{2}\lambda$; (c) $1/3\,\lambda$; (d) $\frac{3}{4}\lambda$; (e) 2λ.

34. The value for the frequency for each tuning fork usually used in the laboratory is (a) found experimentally; (b) found in a handbook; (c) found in manufacturers catalogue; (d) stamped on each tuning fork; (e) not important.

35. When a string vibrates as a whole it produces (a) the fundamental; (b) overtones; (c) harmonics; (d) dissonance; (e) a chord.

36. The most accurate determination of the speed of light was made by (a) Foucault; (b) Michelson; (c) Romer; (d) Galileo; (e) Huygens.

37. The separation of light into its various colors is called (a) a spectroscope; (b) a spectrum; (c) dispersion; (d) polarization; (e) interference.

38. The interference between the direct and reflected wave caused in an air column above a water surface by a vibrating tuning fork is (a) a standing wave; (b) a transverse wave; (c) destructive interference; (d) a radio wave; (e) dispersion.

39. The chief differences between radio waves and light waves is with respect to (a) their velocities; (b) their frequencies; (c) their nature of transmission; (d) their amplitude; (e) more than one of the others.

40. When a solid is heated to incandescence, the type of spectrum that it can produce is (a) continuous; (b) bright line; (c) dark line; (d) absorption; (e) none of these.

41. When one of the rectilinear components of vibration of a light beam is suppressed without affecting the components at right angles to it, the light is said to be (a) refracted; (b) reflected; (c) diffracted; (d) plane polarized; (e) diffused.

42. Spectral lines of a star which are shifted toward the red end of the visible spectrum suggest that the star is (a) approaching the earth; (b) receding from the earth; (c) dying; (d) exploding; (e) being created.

43. The mean distance from the earth to the sun is 93,000,000 miles. The time required for light traveling at 186,000 miles per second to reach earth is (a) 500 sec.; (b) 2 sec.; (c) 118 sec.; (d) 18 min.; (e) less than a second.

44. When a beam of light strikes an irregular reflecting surface the reflected light is spread out in all directions. This process is called (a) refraction; (b) diffused reflection; (c) interference; (d) polarization; (e) dispersion.

45. The sun appears to rise earlier than it actually does. This is due to (a) reflection; (b) refraction; (c) polarization; (d) interference; (e) dispersion.

46. When a beam of white light passes through a glass prism the color which is refracted most is (a) violet; (b) blue; (c) green; (d) yellow; (e) red.

47. Using a resonance tube and a vibrating tuning fork, a determination can be made of a sound's (a) amplitude; (b) timbre; (c) overtones; (d) velocity; (e) harmonics.

48. To distinguish between the fundamental tone and one of the overtones, it is sufficient to know their (a) intensities; (b) amplitudes; (c) frequencies; (d) phase difference; (e) speeds of propagation.

49. If it were not for echoes there would be no (a) reverberation in an auditorium; (b) interference of sound waves; (c) dissonance; (d) resonance; (e) beat.

50. That part of a shadow from which all light is excluded is called (a) the penumbra; (b) total solar eclipse; (c) an opaque body; (d) umbra; (e) sun spot.

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