GRADE PLACEMENT OF AN EXPERIMENTAL UNIT IN SECONDARY SCHOOL PHYSICS

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Department of Education

The University of British Columbia,
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ABSTRACT

This study was designed to determine the relative effectiveness of teaching a unit on wave-motion and sound at the grade nine and ten levels, using two different methods of instruction. One hundred twenty students enrolled in the grade nine and ten General Science courses at the Balmoral Junior Secondary School in School District No. 44 (North Vancouver), took part in the investigation. The students were grouped into three levels of scholastic aptitude within each grade, and also into two methods sections.

Two questions were investigated in this study. First, do significant differences exist between the mean scores on the final test of the various grade and methods groups? Secondly, for which of these groups is the unit suitable? In order to answer the first question, the final scores were studied by an analysis of covariance with scholastic aptitude, knowledge of General Science, and prior knowledge of the material in the unit being the variables controlled. The second question was investigated by first adjusting the final scores of all the subjects for differences between them on the three factors assumed to influence their performance in this study. The performance of each group was then compared with the criterion that 75 per cent of the students in a group should make a mark of 50 per cent or better on the final test in order for the unit to be judged suitable for that group.

All the differences between the means of the two grade groups, and the three levels of scholastic aptitude within these two grades, were found to be non-significant at the one per cent level of significance. On the other hand, the differences between the means of the methods groups, demonstration-experiment and student-experiment, were found to be significant at the one per cent level. Of the two methods groups, the highest adjusted mean score was obtained by the demonstration-experiment group. All the groups satisfied the requirement of suitability that 75 per cent should obtain a mark of 50 per cent or better on the final test.

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CHAPTER I

THE PROBLEM

I. INTRODUCTION

Physicists generally accept that while great progress has been made in the development of new knowledge in their field, there has been no important change in the content of high school physics courses.[1] During the last few years many suggestions have been made to include and develop some of the most important physical principles basic to an understanding of the new developments in physics, at the high school level. Since at present we have very little information regarding the grade level at which the suggested principles can be taught most effectively and the relative effectiveness of different methods of teaching this material, it was felt that research in this area was needed. It is the purpose of this study to provide some objective information concerning the grade placement and relative effectiveness of two different laboratory procedures used in teaching a unit on wave-motion and sound.

A Study of the Criticisms Related to Present Physics Teaching in the Secondary School.

The Physical Science Study Committee was organized in 1956 in order to study the methods and materials used to teach physics in the secondary schools of the United

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1. "A Symposium: The Physical Science Study Committee," Harvard Educational Review, XXIX (Winter, 1959), 1-36.

States.[2] It is from this source that some of the major criticisms and proposals for revising the traditional physics courses have been issued. The Committee has stated its criticisms of the content and objectives of the present or traditional high school physics curriculum in its first annual report.[3] An extensive commentary on the work of the PSSC, both by members of the Committee and by observers from the ranks of educators, mathematicians, and scientists, has been published.[4]

On a local level, the Physics Revision Committee of the Province of British Columbia found that some of the following criticisms made by the PSSC may apply to physics teaching in this province:

1. The physical principles essential to a basic understanding of modern physics have not been given sufficient emphasis.

2. The various topics in the present courses are not related to each other in a way that the student can see the unity of the material within the subject.

3. Insufficient experience has been provided in the type of laboratory exercise that would enable the learner to develop an appreciation and understanding of experimentation as a basic

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2. The Physical Science Study Committee was organized in November, 1956, by Professor Jerold R. Zacharias and colleagues, from both M.I.T. and Harvard, for the purpose of revising the high school physics curriculum. The Committee was primarily supported by the National Science Foundation.

3. <u>First Annual Report of the Physical Science Study Committee</u>. Watertown, Mass.: Educational Services Inc., 1959, pp. 1-30.

4. "A Symposium: The Physical Science Study Committee," <u>Harvard Educational Review</u>, XXIX (Winter, 1959), 1-36.

process of scientific investigation.

4. The method of interpreting data in terms of a theory or model has not been sufficiently emphasized. It is the view of the PSSC that the learner should gain some understanding and appreciation of the use of theories or models in unifying and making scientific knowledge more meaningful.

The Physics Revision Committee was appointed by the Department of Education of British Columbia to recommend a revised programme of physics for the high schools of this province. The point of view described above was obtained verbally from a spokesman for the Committee.

The Physics Revision Programme in British Columbia.

In order to meet the previously outlined criticisms of physics teaching in this province, the Physics Revision Committee of British Columbia instigated an intensive revision programme from grade eight to grade thirteen. The revised programme may utilize some of the PSSC materials, and develop new materials similar to those of the PSSC. One of the members of the committee is also actively engaged in the development of the PSSC programme. In short, the new units of instruction and the experimental apparatus being developed are based on the same principles used by the PSSC.

At the present time this province offers only one physics course, Physics 91, offered in either grade eleven or twelve. Usually, however, physics is not taken by students at the grade eleven level because certain prerequisite courses have not been completed. This break at the grade eleven level was considered a serious interruption in the study of physics, and therefore a two-year programme of physics in grade eleven and twelve seemed desirable. In addition to developing a new two-year programme, substantial teacher training in new methods of teaching high school physics has already begun.[5]

II. STATEMENT OF THE PROBLEM

The purpose of this experiment is to determine the grade placement of an experimental unit on wave-motion and sound by comparing the achievement, as measured by the unit test, of grade nine and ten science students, and by the application of a criterion of suitability in use in this province.

The material in this unit was developed by the Physics Revision Committee described earlier. The following topics were included: the concept of wave-motion as a disturbance that can move from one place to another, the nature of waves traveling along a coil-spring, the superposition of waves, the reflection and transmission of waves upon meeting a different medium, waves in two dimensions, the nature of the motion of two-dimensional waves, reflection and diffraction of two-dimensional waves, sound as a wave phenomenon, the speed of sound waves, the diatonic scale, and harmonics.

The investigation included students enrolled in the

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5. The Physics Department of the University of British Columbia began offering a course in the summer of 1961 to prepare teachers both in subject matter and techniques, as set forth by the PSSC Physics Programme.

Science 10 and Science 20 courses at the Balmoral Junior Secondary School in School District No. 44 (North Vancouver). The students in each course were further divided into three groups on the basis of scholastic aptitude. In addition, the students were also assigned by a random process to two different methods of instruction groups.

Using these materials, with these subjects, the following specific problems were studied:

1. Is there a significant difference in the mean achievement scores as measured by the Unit Test of the Science 10 and Science 20 groups?
2. Do the mean achievement scores as measured by the Unit Test of the upper-third in each of the two science courses differ significantly?
3. Are the mean achievement scores as measured by the Unit Test of the middle third of each of the two science courses significantly different?
4. Is there a significant difference in the mean achievement scores as measured by the Unit Test of the lower-third students in each of the two science courses?
5. Is there a significant difference in the mean scores of achievement as measured by the Unit Test obtained by the demonstration-experiment and the student-experiment groups?
6. At which grade level, nine or ten, and for what experimental group was this unit suitable? As a criterion for determining whether the unit was suitable for a group, 75 per cent of the students in that group were required to obtain a score of 50 per cent or better on the Unit Test.

The hypotheses tested in this study, stated as null hypotheses were as follows:

1. No statistically significant difference occurs between mean scores of ninth and tenth graders on the achievement of the unit.

2. Mean scores of the upper-third groups at the two grade levels do not differ significantly on achievement of the unit.

3. Mean scores of the middle-third groups at

the two grade levels do not differ significantly on achievement of the unit.

4. Mean scores of the lower-third groups at the two grade levels do not differ significantly on achievement of the unit.

5. No statistically significant difference occurs between the mean scores of the demonstration-experiment group and the student-experiment group on achievement of the unit.

III. JUSTIFICATION FOR THE EXPERIMENT

The Importance of the Unit.

It is intended that this unit should be taught at either the grade nine or ten level. The unit should be taught before grade eleven for four reasons:

1. The material is essential to the new two-year programme that will begin in grade eleven.

2. The attitudes and skills that this unit of work is designed to develop are considered essential as a proper background for the work in the next two years.

3. A relatively small number of students enroll in physics beyond the general science course in grade ten, so this is the last year in which fairly difficult and new concepts can be presented to a large number of students.

4. The unit lends itself to teaching utilizing the laboratory. However, the amount of freedom that a student should have in terms of responsibility in carrying out these laboratory investigations needs to be determined.

In the light of these considerations, the suitability of this unit for both grade nine and ten seemed worthy of investigation.

Necessity of Objective Information for Grade Placement and Methods.

In order to place an experimental unit at the appropriate grade level, criteria for grade placement should be established. The Committee felt that in addition to the opinions received from teachers using the new unit in their classes, controlled experimentation with grade placement would provide more objective evidence.

Walters[6] found for several units of subject matter in high school biology that an added year of maturity did not produce significant differences in the mean achievement scores at the grade nine or ten levels. On the other hand, Grant[7] in a study of the grade placement of a unit in high school mathematics material, found that an added year of maturity did make a significant difference in the mean achievement scores and the suitability of the unit to a particular grade. A comprehensive survey of Science Education Research made by Meppelink[8] failed to provide any evidence on the grade placement of the material in the unit used in this study. For these reasons, it seemed desirable to obtain objective information for the grade placement of this physics unit.

As to the effectiveness of various teaching methods,

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6. Louis L. Walters, "A Comparison of Achievement in High School Biology When Taught to Ninth Grade and Tenth Grade Pupils" (unpublished Doctor of Philosophy thesis, The University of Minnesota, Minneapolis, 1961), p. 101.

7. Douglas R. Grant, "Grade Placement of Symbolic Logic" (unpublished Master's thesis, University of British Columbia, Vancouver, 1961), p. 42.

8. Fred Meppelink, Jr., "An Annotated Bibliography of Science Education Research Published 1938-1960." (unpublished Master's thesis, Western Michigan University, Kalamazoo, 1961), pp. 30-140.

a survey of studies[9] made since 1920 showed that...

> "...no one general teaching method, that is methods such as the lecture, discussion, tutorial, reading-study in which the 'tactics' of teaching are emphasized, is better than another. However, there is considerable evidence that teaching effectiveness can be increased by employing problem-solving methods. The important thing is that, directed by appropriate teaching, the student should enquire into, rather than be instructed in, subject matter."

The problem of whether the student needs direction has been investigated to a considerable extent. The conclusions of the more recent studies are that in the development of concepts, and in the related task of guidance of students in problem-solving, the teacher must present clues....for the purpose of directing the students to the successful discovery and application of essential discriminations and relationships.[10] The question of how much direction and in what form the direction should be given for maximum effectiveness appears to be unanswered.[11]

Scientists use the laboratory as a primary place for learning; it seems that a similar function should be served in the teaching of science. One purpose of laboratory work is to acquaint students with the processes of inquiry as a means to explore and develop ideas. The student is concerned with: What questions should be raised? What data are

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9. U. S. Department of Health, Education, and Welfare, Office of Education, <u>New Dimensions in Higher Education</u> (Effectiveness in Teaching No. 2. Washington,D.C.:1960),p.15.

10. <u>Ibid</u>. p. 16.

11. <u>Ibid</u>.

relevant? How can observations be made and expressed in the most meaningful way? How should the data be ordered for interpretation? However, data, known and analyzed, do not give a "conclusion"; theories and models are needed also to help synthesize the data, give meaning to the experiment, and to describe conditions which permit predictions.[12]

Laboratory activities are often defined to include demonstrations as well as individual or small group activities, and to some, any differentiation between these laboratory activities and demonstrations seems artificial. In either case, the presence of one laboratory activity or another does not guarantee the realization or lack of realization of the goals. The results achieved in the laboratory depend upon how this facility is used. Further, the way the laboratory is used depends upon the degree of responsibility of action that the teacher assumes in the teaching-learning process.[13]

At one extreme, the teacher assumes that his responsibility is to dispense knowledge, the laboratory being used for drill (reinforcement) or verification. At the opposite extreme, the teacher assumes that his responsibility is to serve as a consultant, the laboratory being used to discover

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12. Paul DeHart Hurd, "The New Curriculum Movement in Science--An Interpretive Summary," The Science Teacher, XXIV (February, 1962), p. 29.

13. Milton O. Pella, "The Laboratory and Science Teaching," The Science Teacher, XXVIII (September, 1961), pp. 29-31.

knowledge. In between these extremes is the utilization of the laboratory for helping students develop an understanding of scientific principles inductively. The student in this kind of laboratory program is made aware of the facts supporting a generalization and the relationship of the facts to each other so that common factors or trends can be ascertained.

Involved in the process of securing scientific knowledge through the use of the laboratory are several common steps. The following are recognized as the "type form" given for scientific problem solving:[14]

1. Statement of the problem.
2. Formulation of hypothesis.
3. Developing a working plan.
4. Performing the activity.
5. Gathering of data.
6. Formulation of conclusions.

In the utilization of the laboratory to help students gain an understanding of scientific knowledge, there are several degrees of responsibility of action that the teacher and the student can assume. These degrees of responsibility of action are in relative amounts of responsibility assumed by the teacher and students. The six teaching procedures given in Table I represent six degrees of responsibility of student and teacher action that could be used in the laboratory.

In the column denoting Procedure I, the teacher performs all the steps in solving the problem except gathering the data and formulating the conclusions. If the teacher

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14. Pella, <u>op</u>. <u>cit</u>., p. 31.

employs Procedures II or III, the students will, in addition to gaining information, have an opportunity to develop laboratory skills. The methods of science are generally approached in Procedures V and VI, while individual research is encouraged when the activities of the student parallel Procedure VI.

TABLE I

DEGREES OF RESPONSIBILITY OF ACTION AVAILABLE FOR THE TEACHER AND STUDENT USING VARIOUS LABORATORY PROCEDURES

	Laboratory Procedures					
Steps in Procedure	I	II	III	IV	V	VI
1. Statement of Problem	T	T	T	T	T	T
2. Hypotheses	T	T	T	T	P	P
3. Working Plan	T	T	T	P	P	P
4. Performance	T	P	P	P	P	P
5. Data Gathering	P	P	P	P	P	P
6. Conclusion	P	P	P	P	P	P

T - teacher action   P - student action

The above description of teaching methods, and in particular the laboratory method, was intended to provide the setting in which the two laboratory procedures investigated in this study have a place. More specifically, part of the problem in this study was to determine the relative effectiveness of two laboratory procedures differing in the amount of responsibility of action assumed by the student and teacher. These two teaching procedures are listed as Procedures I and

II in Table I, and are defined in the next section.

IV. DEFINITION OF TERMS USED

Demonstration-experiment.

For the purpose of this study, demonstration-experiment shall mean the laboratory procedure whereby the teacher presents an appropriate problem, suggests hypotheses, presents a working plan, performs the experiment, but requires that the students gather and interpret the data themselves. The formulation of the conclusion is the responsibility of the students alone.

Student-experiment.

In this study, student-experiment shall mean the laboratory procedure whereby the teacher presents the problem, suggests hypotheses, presents a working plan, but the performance of the experiment, the gathering of data, and the formulation of the conclusion are left to the students.

CHAPTER II

SURVEY OF THE LITERATURE

This chapter is concerned with establishing the place of this study in its broad educational context. To accomplish this objective, recent trends in science education such as the changing philosophy of curriculum and learning, course revision projects and their objectives, grade-placement studies, and methodology studies will be identified and described.

I. THE EDUCATIONAL CONTEXT OF THE STUDY

A Survey of the Changing Trends in Science Education[15]

One of the basic issues in today's debate about the public schools is the proper relationship between academic fields such as physics and the curriculum of the elementary and secondary schools. Two generations ago this question was not debated very much, for it was assumed that the schools should present each major discipline as a separate subject. The school emphasized the academic disciplines although other factors such as the capacity of the learner and the needs and demands of society influenced the school curriculum directly or indirectly. It was generally assumed that society's needs would best be met by transmitting as much as possible of the organized available knowledge.

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15. D. M. Fraser, "Current Curriculum Studies in Academic Subjects," A Report Prepared for the Project on Instruction, (Washington, D.C.: National Education Association, 1962), pp. 1-26.

With the rise of systematic studies of human behaviour and development, the emphasis shifted to a consideration of the nature of the student, his learning processes, and more explicitly, stated social goals as the major bases for selection of curriculum content. The concept of student readiness was given much emphasis in selecting content for students at any particular stage of maturity. Readiness was considered an integral part of maturation--a process that had to develop according to the child's natural growth pattern. Disciplines such as physics were considered as reservoirs from which careful selections of content were made and organized into a curriculum that would meet the changing needs of society and the learner. This trend represented a drastic change in the basis for content selection and in the structure around which the content was organized. Since the study of the academic disciplines was not a primary consideration, academic specialists took less and less part in planning the school curriculum.

In the past ten years, there have been new pressures to teach a discipline such as physics, as physics, in the schools, to start the subject at an earlier age or grade level, and to stress the structure of the academic discipline. Some of these pressures arose because of the longer time required to prepare a scientist, doctor, or other professional in a specific field, and the consequent demands that students enter university prepared for more advanced studies. Furthermore, it became increasingly clear to some people that the traditional subjects could well serve as a means of organizing and expanding man's knowledge and as a useful framework for research. Other pressures came about because of the realization that, with the decline in participation of the academic specialists in planning the curriculum, the school was far behind in introducing the findings of recent scholarship. For example, the basic concepts of quantum mechanics such as the wave-particle nature of electromagnetic radiations, matter-waves, and the basic ideas of relativity have not yet been included in the curriculum.

The concept of the readiness of the student has been central in deciding what to teach at a certain grade level and how to organize that material. This concept is being seriously re-examined today, and the different points of view about it are being expressed and applied to curriculum revisions. An important opinion is that many physical concepts can be taught intuitively before the students are ready for analysis of a more abstract nature, and children can be helped to attain readiness for more involved thought processes earlier if they are given practice in such methods of thinking.[16]

This reconsideration of the relationship of the academic disciplines to the school curriculum has gained momentum. Special projects, which will be described later in this chapter, have been set up to study certain areas of the

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16. Jerome S. Bruner, The Process of Education (Cambride, Mass.: Harvard University Press, 1960), pp. 33-54.

present curriculum. The goal of most of these groups is to close the gap between recent research findings in the academic fields and the related subjects in the schools. Academic specialists are playing a leading role in these projects. Most of these groups have made recommendations for changing specific subjects of the school program, or have produced specific course plans and learning materials through which their plans can be implemented. Although most of these projects are concerned with students that have sufficiently high scholastic aptitude for college work, some are designed to influence programs for all students, from the slow to the gifted. A number of these projects are still in the beginning stages; a few of them, chiefly those that have been in operation for a number of years, already have had a considerable impact on existing school programs and on plans for the future. The influence of the other projects remains to be seen.

So far most of the major curriculum projects in secondary school science have concentrated on single subjects within the field of science, such as physics, chemistry, and biology. The two main purposes of these courses are: (a) to contribute to the general education of the students and (b) to serve as an appropriate introduction to a specialized field of science. Some leaders in science education are expressing concern about the lack of attention given by these projects to the total science sequence from grade one to grade twelve. They point out that although a particular course may be excellent in itself, it may handicap the learner if it fails to provide for a cumulative development of science concepts.

Studies in elementary school science are also being conducted and will be described briefly later in the chapter. A number of these studies are trying to discover which basic science concepts can be taught effectively to young children; in others, the emphasis is on exploring the needs and possible procedures for developing science programs in the elementary school.

The above outline is intended to provide the broad educational context in which this study took place. The more localized context was that, in this province, an intensive science revision program has begun. The program has been authorized by the Department of Education of this province.

In 1960 the Department appointed a Revision Committee to study the present science program and to make recommendations. The committee has studied the provincial science curriculum in the light of the educational setting described above and in terms of local needs and demands. Consequently, new units of study and courses were prepared for classroom experimentation in a number of schools. The proposed changes involved grades eight to thirteen. The purpose of this study is to provide objective evidence on the grade placement and method of study to be used for a specific unit drawn up by the Committee.

Current Major Science Revision Projects

The first of the major studies, and the one nearest to to the completion of its initial purpose, is the PSSC program which began in 1956.[17] The group prepared a syllabus and learning materials to implement the program. These materials include a textbook, laboratory apparatus and guides to be used with the text, a series of sixty films to be used with the textbook, teacher's guides, and examinations. The Educational Testing Service assisted the Committee in developing the testing program. During 1961-62, nearly 1800 teachers were using the new physics course.

The PSSC course is organized around the basic concepts that form the structure of modern physics and provides for study of these selected concepts in greater detail. The course does not include many of the topics in existing physics programs, particularly technological applications. Many of these topics and applications, it was felt, should be taught in science courses in lower grades.

The Committee proposed from the beginning that students should gain an understanding of the processes of scientific study as well as the current conclusions in physics. In order to promote learning through discovery, open-ended laboratory work was prepared. Such materials minimized directions to the students participating in the experiments. The films showed extensions of the experiments that would be too elaborate or that would require a high level of technique.

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17. A Review of the Secondary School Physics Program of the Physical Science Study Committee, (Watertown, Mass., Educational Services, Inc., 1959), pp. 1-47.

The course was designed for students likely to study physics in United States high schools, mostly in the upper 25 per cent of scholastic aptitude. The testing program has indicated that the course is well within the ability of this group and that many students who ranked around or somewhat below the seventy-fifth percentile on the scholastic aptitude scale (SCAT) do well in the course. The evaluation program is still in progress.

Since the PSSC course has played a major role in the British Columbia science revision program, a more extensive evaluation of it is thought to be necessary. A study of how effective the PSSC program is in preparing students for traditional physics courses in college has been made. Hipsher[18] compared the relative effectiveness of traditional high school physics as taught in a particular school with the PSSC course taught in the same school. The control group received the traditional course while the experimental group received the PSSC course. The criterion was the Co-operative Physics Test. Four variables were held constant: scholastic aptitude, prior achievement in natural science, physical science aptitude, and socio-economic status. Both groups were taught by the same teacher in the same classroom for the same length of time and in comparable-sized groups. The dependent variable was the curriculum used to teach high school physics. The observed differences in

18. Warren L. Hipsher, "Study of High School Physics Achievement," <u>The Science Teacher</u>, XXVIII (October, 1961), pp. 36-37.

Cooperative Physics Test scores between the two groups, with the independent variables held constant, were significant at the .01 level of confidence. Although the group that received the traditional course did significantly better on the test, the criterion used in this study was acknowledged to be designed for the purpose of measuring achievement in physics when a traditional course had been in use. Since the criterion used for measuring achievement was designed for a traditional physics course, the control group may have obtained a higher achievement level for this reason. Since many colleges and universities are oriented toward traditional physics in their introductory course in physics, the preparation of high school graduates to succeed in a traditional physics curriculum at the college level might be one of the expectations and requirements for any high school physics program. It would seem desirable therefore, that any new physics program should include a considerable amount of traditional physics until the introductory courses at the college level are revised along similar principles to the changes proposed in such a course as the PSSC has developed.

The National Science Teachers Association[19] has developed policy statements concerning the teaching of

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19. This summary is based on the following policy statements: (a) National Science Teachers Association, _It's Time for Better Elementary School Science_ (Washington, D.C.: National Education Association, 1958), pp. 1-48. (b) National Science Teachers Association, _Planning for Excellence in High School Science_ (Washington,D.C.: National Education Association, 1961), pp. 1-67.

science in secondary and elementary schools. They have listed a number of shortcomings of the existing science curriculum. Among others, they have stated that present science courses cover too many areas within one field of science; that students do not get an adequate picture of modern science; that content and technology are overemphasized to the neglect of laboratory experiences; that the laboratory experiences provided do not promote understanding of the nature and techniques of scientific discovery; and finally, that the present science curriculum does not challenge the intellectual resources of many students.

The policy statements recommend that continuity in the cumulative development of the basic generalizations and concepts that provide structure in the various fields should be stressed. By the end of their elementary-school experience, pupils should have developed curiosity and enthusiasm for the study of science topics. They should have acquired habits of systematic classification of their observations and made a beginning in quantitative thinking and representation. The modes of scientific thought and some aspects of the history of science should be familiar. They should have the beginnings of a scientific vocabulary and have developed a desire for scientific explanations of observed phenomena.

Through their study of science in the junior high school years, students should have acquired a basic knowledge of the nature of science, its process, and the tentative and cumulative nature of scientific knowledge. Students need to improve their mathematical, observational, and experimental skills as well. Lastly, students should become increasingly aware of the concepts and theories which describe and unify the fields of science.

In the secondary-school years, the Association recommends that at least two science courses be taken--one in the life sciences and one in the physical sciences. Students with special science interests and aptitudes should take more than these two basic courses. The courses should stress the process of the methods of exploring and developing scientific knowledge.

The Science Manpower Project[20] began a five-year project in 1956 for the purpose of preparing an articulated proposal for a science program extending from kindergarten to grade twelve. The proposals are now available as guides in modifying and updating present science programs. The proposals are prepared in the form of monographs and deal with elementary science, the junior high-school program, and biology, physics, and chemistry in the secondary high school program.

In 1959, the University of California Elementary School Science Project[21] was organized. The personnel was composed of ten scientists, one professional educator, four

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20. Bureau of Publications, Teachers College, The Science Manpower Project (New York: Columbia University, 1959), pp. 1-12.

21. David C. Ipsen, "Elementary School Science Project," Science Education News, (December, 1961), p. 3.

elementary school teachers, and four technical writers. They have directed their attention to the development of a series of units intended to demonstrate to young children the nature of scientific investigation and analysis. Each unit represents the thinking of one of the members in the project. Five units have been tried at least once in the schools and are now being revised. They deal with the following topics: coordinates, force, human physiology, natural selection, and the structure and properties of matter.

The Science Curriculum Improvement Study[22] grew out of the work of the California Elementary School Science Project. The Study began in 1961 for the purpose of carrying out a series of experiments designed to develop a concept of science instruction for elementary-school children based on the nature and structure of science, and to develop materials for such instruction. The rationale of the Study emphasizes the teaching of a conceptual framework--the scientific point of view--within which children can perceive and interpret scientific phenomena in a meaningful way and organize their inferences into generalizations of lasting value. The immediate aims of the Study are to investigate aspects of basic science that can be understood by elementary-school pupils and to develop effective teaching plans for

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22. Robert Karplus, "The Science Curriculum Improvement Study" (Berkeley, California: University of California, 1961), p. 7. (Mimeographed.)

these topics.

The University of Illinois Elementary School Science Project[23] begun in 1960 under the codirectorship of a professional educator and an astronomer, emphasizes teaching the structure of astronomy. It is their opinion that the initial guideline for curriculum construction is the discipline itself. The apparent interests of the students and the social utility of science are important, but they feel that a deep interest in science can result from an understanding of the subject.

Because of the interdisciplinary character of astronomy, this topic was chosen for the Project's initial effort. The results have produced experimental editions of two booklets--"Charting the Universe" and "Gravitation." The two booklets were given field tests in 1961-62 with about 250 teachers and 7,500 children. Additional materials and revisions of the present program are planned for 1963.

Three regional conferences were held during 1960-61 to explore the kinds of studies that could contribute to the improvement of science programs at the elementary and junior high school levels. These conferences resulted in a project called the Feasability Study in Elementary and Junior High School Science of the American Association for

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23. Myron J. Atkin, "The University of Illinois Elementary Science Project," Elementary School Science Bulletin, (December, 1961), p. 3.

the Advancement of Science.[24] The consensus of the participants was that the emphasis in instruction should be the discovery of scientific knowledge, the learning of methods of observation, and interpretation of data simultaneous to learning course content.

Preparation of alternative science programs and materials is in progress. The pattern--set by other recent curriculum studies--of drafting materials, classroom trial, revision in the light of results in the classroom, and publication for general school use was adopted as being the most useful approach.

An attempt has been made here to describe the nature of some of the current curriculum studies in science for the purpose of establishing the context in which this study appears.

Since this study was concerned with an experimental unit in physics, a survey of published grade-placement and methodology studies related to this subject is now made. The literature surveyed covered a period of time from 1938 to 1960.

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24. Steering Committee of the American Association for the Advancement of Science, "Science Teaching in Elementary and Junior High Schools," Science, CXXXIII (June, 1961), pp. 2019-2024.

II. GRADE-PLACEMENT AND METHODOLOGY STUDIES IN SECONDARY SCHOOL PHYSICS

A comprehensive survey of the science education literature published in media having a wide circulation among science educators has been made.[25] The survey was prepared for the purpose of organizing the literature in this field in order to facilitate studies in science education and to provide a working bibliography for use in the preparation of two digests in science-education research.

This survey had listed 339 science-education research studies at the secondary school level. Of these, twenty-two were directly concerned with the teaching of physics. Only six of these studies were related to methodology of instruction, and five with grade-placement of topics in this subject.

Of the methodology studies in physics reported, none dealt directly with the methods investigated in this experiment. They were primarily concerned with the effectiveness of television instruction, the use of films, the use of basic algebra, and the integration of physics with chemistry.

Furthermore, none of the reported grade-placement studies were directly related to the problem of this

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25. Fred Meppelink, Jr., "An Annotated Bibliography of Science Education Research Published 1938-1960." (unpublished Master's Thesis, Western Michigan University, Kalamazoo, 1961), pp. 30-140.

experiment. The reported studies were concerned with the rating of the difficulty of words in existing texts, ranking principles of physics in order of importance, and appraising the amount of algebra needed in a traditional high-school physics course.

Although many experimental physics courses have been tried out in classroom situations, the reported findings of grade-placement and methodology studies of the type conducted in this experiment seem to be in other fields rather than in physics. Much of the information reported in the journals on curriculum revision, although carefully reported, is still rather subjective. Evans[26] points out the need for a break-through to a firmer research base for making decisions and planning organizational operations. The prevailing method of conducting curriculum revision still seems to be based primarily on experts' opinions. The present study suggests a more rigid design.

In a grade-placement study in arithmetic, Washburne and the Committee of Seven[27] used the principle of establishing an arbitrary criterion of suitability that three-quarters of the students in a particular grade were required to obtain a mark of 50 per cent before a topic was considered suitable for that grade. The principle of using an arbitrary

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26. H. M. Evans, "Organization for Curriculum Development," Review of Educational Research, XXVII (June, 1957), pp. 291-292.

27. Carleton W. Washburne, "Mental Age and the Arithmetic Curriculum," Journal of Educational Research, XXIII, (March, 1931), pp. 210-231.

criterion of suitability for establishing whether a topic is suitable for a grade or not, was also used in this study.

The PSSC has described the nature and purpose of the pupil-experiment method of instruction. It was decided that this method of learning a topic would be compared in this study with a more traditional method--that of teaching by teacher-conducted demonstrations.

In general, many revisions of science courses are underway. This is also true on a more local level. Although many of these experimental units have been tried out in classroom situations, there have been few studies designed to determine the grade-placement of a specific topic in physics. Such studies have been conducted in other connections. Specifically, Washburne studied the grade-placement of topics in arithmetic at the elementary-school level and applied the principle that in order for a topic to be considered suitable for a particular grade, the students for that grade would have to achieve the arbitrary level of competence described earlier. This study is designed to investigate the grade placement of a unit in physics by applying the principle of achieving an arbitrary level of competence defined by the Physics Revision Committee for determining the suitability of a unit of study for a particular grade. In addition, a study of the relative effectiveness of the student-experiment approach suggested by the PSSC was compared with a more traditional method, that of teacher-conducted demonstrations.

CHAPTER III

THE EXPERIMENTAL UNIT AND TESTS

In order to answer the questions stated earlier, a series of lessons, and a unit test were prepared and presented to the subjects. At the conclusion of the unit, the scores made on the final unit test by each group were analyzed. Decisions were then made on the basis of a predetermined criterion regarding the suitability of the material for the two grade levels.

The experimental unit in wave-motion and sound was composed of a series of lessons followed by a final test. Each lesson presented the new problem in relation to the previous lessons, raised specific questions to be investigated and outlined experimental procedures.

I. CONTENT OF THE UNIT

The unit on wave-motion and sound was developed and prepared in outline by the Physics Revision Committee of the Province of British Columbia. Using this outline, a series of lessons and a unit test were prepared for this study.

Description of the Lessons.

The unit consisted of thirteen lessons. The topic of each lesson is given in Table II. The lesson plans have been presented in Appendix A. Lesson plans were used to insure uniformity of the questions and procedures of investigation for the various experimental groups.

TABLE II

CONTENT OF THE LESSONS

Lesson	Topic
1	A Wave: Something Else That Travels
2	Waves on A Coil Spring
3	Superposition of Waves
4	Reflection and Transmission of Waves
5	Standing Waves
6	Waves in Two Dimensions
7	Reflection of Waves in Two Dimensions
8	Diffraction of Waves
9	Sound: A Wave Phenomenon
10	Sound Waves
11	The Speed of Sound Waves
12	The Diatonic Scale
13	The Quality of Sound

All the subjects were required to keep a log book giving a brief description of what they did and to what conclusions they came. No homework was assigned to any of the groups. At the same time students were also asked to keep a record of any additional reading that they did about the topics in the unit.

II. DESCRIPTION OF STANDARDIZED TESTS USED

The standardized tests were used as pre-tests and were administered prior to the experiment.

The Scholastic Aptitude Test.

In order to obtain a measure of the scholastic aptitude of the subjects for the purposes described in Chapter

I, the Henmon-Nelson Test of Mental Ability, Grades 9-12, Form A, was administered to all subjects taking part in this study. In order to insure uniform testing conditions as much as possible, all the subjects were tested at the same time, in the same room, by one examiner.

The General Science Test.

In order to determine whether the experimental groups had comparable knowledge of general science prior to the experiment, the Read General Science Test, Form AM, was administered to all the students, The relative emphasis of the various fields of science covered was stated in the Manual of Directions[28] as 42 per cent physics, 28 per cent biology, 4 per cent chemistry, and 26 per cent general.

The topics covered in physics included: air, water, heat, light, sound, work and machines, and electricity.

III. CONSTRUCTION OF THE UNIT TEST

In order to determine whether the groups had a comparable knowledge of the specific content of the experimental unit before instruction, and in order to measure achievement of the subject matter after instruction, a unit test was constructed.

Selection of the Items.

The items in the test were written under the supervision

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28. John G. Read, Manual of Directions for the Read General Science Test (New York: World Book Company, 1951), pp. 1-4.

of a scientist on the Physics Revision Committee of this province. Each item was checked for clarity, vocabulary, difficulty, scientific accuracy, and content validity. An analysis of the kind of content approved by the Committee is given later in this chapter. In addition, after the unit was completed and the unit test given, the students were asked to criticize each item on the basis of clarity and vocabulary difficulty. Any item for which there was any misunderstanding was dropped from the test for purposes of analysis. The remaining forty items were judged by members of the Revision Committee to provide a representative sample of what they hoped the students would achieve from studying this unit of work.

In selecting the items for the final form of the test, statistical evidence for the suitability of the difficulty and discriminating power of each item was also considered. Table III presents a summary of the difficulty and discrimination indices for each item of the test. The mean difficulty index was .54 while the mean discrimination index was .51. These calculations were based on the responses made by all the subjects used in this study.

The method used to compute these indices was given by Davis.[29] The procedure involved computing the percentage of correct responses to each item of the highest and lowest 27 per cent of the two grade groups. These two percentages

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29. F. B. Davis, Item Analysis Data (Harvard Education Papers. Cambridge, Mass.: Graduate School of Education, Harvard University, 1949), pp. 15-16.

were then used to enter the item analysis chart prepared by Davis in order to obtain the two indices.

TABLE III

ITEM DIFFICULTY AND DISCRIMINATION INDICES

Item	Difficulty Index	Discrimination Index	Item	Difficulty Index	Discrimination Index
1	.63	.59	21	.83	.47
2	.61	.52	22	.51	.35
3	.47	.31	23	.76	.59
4	.87	.51	24	.24	.72
5	.39	.71	25	.43	.68
6	.30	.77	26	.04	.40
7	.39	.41	27	.62	.64
8	.74	.49	28	.51	.74
9	.62	.43	29	.66	.36
10	.62	.43	30	.06	.30
11	.43	.68	31	.32	.61
12	.62	.72	32	.47	.35
13	.32	.73	33	.70	.38
14	.66	.54	34	.89	.48
15	.77	.42	35	.40	.54
16	.57	.29	36	.51	.61
17	.49	.27	37	.49	.58
18	.36	.57	38	.55	.54
19	.66	.45	39	.55	.54
20	.91	.28	40	.72	.52

In selecting the items, the suggestiom made by Garrett[30] that discrimination indices .20 and higher are useful, was followed. Although the item difficulty was not

30. Henry E. Garrett, Statistics in Psychology and Education (New York: Longmans, Green and Company, 1960), p. 364.

controlled, the indices were computed to show the extent to which the items were suitable for the wide range of scholastic aptitude possessed by the students.

Test Reliability.

An estimate of the reliability of the test was determined by using Hoyt's[31] variation of Kuder and Richardson's formula twenty. The coefficient obtained in this way was actually a measurement of the internal consistency of the test; however, under certain conditions it will tend to provide a minimum estimate of reliability.[32]

Since this formula is not applicable to speed tests, it was necessary to insure that time was not a factor. Almost all the students finished the test in thirty minutes. Since fifty minutes was allowed for the test, all students had ample time to try the items and to check their answers.

Using this method, the reliability coefficient of the test was .79. Since it was difficult to interpret this coefficient in terms of the fluctuations in the test results of an individual student that might be expected from one testing to another, the standard error, which is an estimate of the amount by which an individual's score is likely to vary from his true score, was computed. The standard error of measurement was 2.71 for a total of forty items.

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31. C. J. Hoyt, "Note on A Simplified Method of Computing Test Reliability," Educational and Psychological Measurement, I (January, 1941), pp. 93-5.

32. Garrett, op. cit., p. 386.

Content Validity.

The extent to which the test was a valid measure of the material of the unit as outlined in the lesson plans was established by the method of constructing the test. A content analysis of the items of the test is shown in Table IV. The table shows how the items covered the content and the kind of items considered important by the Committee.

The content analysis showed that in the opinion of the Committee, 75 per cent of the items required that the student apply his knowledge of the subject matter to situations that were somewhat different from those actually studied in class. This selection of items was judged acceptable by members of the Revision Committee.

TABLE IV

CONTENT ANALYSIS OF TEST ITEMS

Topic	Factual Knowledge	Application of Knowledge
Definition of a pulse	1	
How waves travel through a medium	1	1
Definition of a medium	1	
How "S" and "P" waves travel		4
The speed of "S" and "P" waves		2
Reflection and transmission of pulses		4
Characteristics of standing waves	2	3
Definition of frequency	1	
Generating different shaped water waves		2
Reflection of water waves		4
Diffraction of water waves		4
Pitch of a sound	1	
Amplitude of sound waves	1	
Speed of sound waves	1	2
Transmission of sound waves		1
The diatonic scale	1	1
The quality of sound		2
Total	10	30

CHAPTER IV

METHOD OF EXPERIMENTATION

I. THE SUBJECTS

The design of this experiment involved the utilization of various experimental groups drawn from seven classes of grade nine and ten General Science over a period of one month. Pre-tests were administered in order to permit the statistical control of certain factors assumed to be able to influence the post-test scores significantly. During the experiment, two methods of instruction were employed--the demonstration-experiment and the student-experiment method. Following the instruction period, a unit post-test was administered and the resulting scores analyzed. The statistical analysis involved a comparison of achievement of the experimental groups and the application of pre-determined criterion of suitability.

<u>Description of the Subjects</u>.

The subjects used in this experiment were all students of the Balmoral Junior Secondary School, District No. 44 (North Vancouver). Those students registered in grade nine General Science (Sc. 10) were used as a sample of grade nine science students while those registered in grade ten General Science (Sc. 20) represented a sample of grade ten science students.

Selection of Subjects and Groups.

Table V shows that there were 198 students enrolled in Sc. 10 and 106 in Sc. 20. Furthermore, the table shows that instruction blocks A, B, C, and D were the same for the two grade groups. Since facilities at the school were inadequate for combining the students in these blocks for purposes of the experiment, a 100 per cent sample was considered to be too inefficient to handle. Instead of using

TABLE V

NUMBER OF STUDENTS REGISTERED IN GRADE NINE AND GRADE TEN GENERAL SCIENCE

Instruction Block	A	B	C	D	E	F	G	Totals
Sc. 10	27	26	33	34	27	29	32	198
Sc. 20	28	27	19	32				106

all the students available for this study, it was decided that two random samples of sixty students would be drawn from each of the total Sc. 10 and Sc. 20 groups. A table of random numbers was used for this selection.[33] Table VI shows how the samples were distributed in the instruction blocks.

33. H. M. Walker and J. Lev, Statistical Inference (New York: Henry Holt and Company, 1953), pp. 484-5.

TABLE VI

DISTRIBUTION OF STUDENTS IN THE RANDOM SAMPLES AMONG THE DIFFERENT INSTRUCTION BLOCKS

Instruction Block	A	B	C	D	E	F	G	Total
Sc. 10	7	7	12	5	7	8	14	60
Sc. 20	15	18	11	16				60

The scholastic aptitude of the subjects used in this study was measured by means of the <u>Henmon-Nelson Test of Mental Ability</u>. Table VII summarizes the mean IQ score of each of the two grade groups, as well as the standard deviation of each IQ distribution.

TABLE VII

SCHOLASTIC APTITUDE OF STUDENTS IN THE SAMPLES DRAWN FROM SC. 10 AND SC. 20

Grade Group	Number of Students	Mean IQ	S. D.
Sc. 10	60	115.5	11.9
Sc. 20	60	123.4	9.6

Insofar as Balmoral Junior Secondary School was representative of secondary schools in this province, Table VIII shows that the grade nine and ten samples used in this study appear somewhat superior in terms of scholastic aptitude to other grade nines and tens in this province.

TABLE VIII

SCHOLASTIC APTITUDE OF A SAMPLE OF GRADE NINE AND GRADE TEN STUDENTS IN THE PROVINCE OF BRITISH COLUMBIA[34]

	Grade 9 Henmon-Nelson H. S. B.	Grade 10 Otis S. A. Higher C (Estimated)[35]
Mean IQ	107.1	104.8
S. D.	14.2	11.2

In order to permit the comparison of achievement of the various levels of scholastic aptitude within a grade group, each sample of Sc. 10 and Sc. 20 students were ranked on the basis of the IQ scores obtained on the Henmon-Nelson test, and divided into three equal groups on the basis of scholastic aptitude. Finally, the two different methods sections within each grade group were selected by means of random numbers. Table IX shows the sizes of the various experimental groups and how they were classified for purposes of analysis.

Although all the groups were of equal size when the samples were selected, one subject left the school and four

34. Division of Test, Standards and Research, B. C. Scholastic Aptitude Norms (Victoria, B. C.: Department of Education, Division of Tests, Standards and Research, 1961).

35. A province-wide survey at the grade ten level has never been made. However, the Director of the Division of Tests and Standards in this province has provided an estimate of what such a survey might have produced using the Otis test.

were absent one instruction period during the experiment. The assumption was made that these events were due to factors which would not result in any bias in the experiment. The pupils who were absent made special arrangements to make up the lesson in another block.

TABLE IX

CLASSIFICATION AND SIZE OF EXPERIMENTAL GROUPS

Grade Group	Scholastic Aptitude	Method of Instruction: Demonstration-Experiment	Method of Instruction: Student Experiment	Totals
	Upper Third	10	10	20
9	Middle Third	10	10	20
	Lower Third	10	10	20
	Upper Third	10	10	20
10	Middle Third	10	10	20
	Lower Third	10	10	20
	Totals	60	60	120

II. EXPERIMENTAL PROCEDURE

All the students except the students in the Sc. 10 sample from blocks A, B, C, and C, were given the experimental unit during their regular science period. The instruction was directed at a level and time limit specified by the Revision Committee. Thirteen lessons were required to teach the material prescribed.for the unit of study by the Committee.

In the first ten minutes of each instruction period, the entire class was briefed on the new lesson. The new problem was clarified, related to the previous day's lesson, and special technical information on the use and care of the apparatus was given. Following this brief orientation period the student-experiment and the demonstration-experiment groups separated. The student-experiment group stayed in their regular classroom under the supervision of their regular teacher. The other group went to another room in the school where they received instruction from the experimenter.

The regular teacher gave each student a lesson sheet to be used in studying the new problem. The lesson sheet contained technical information on how to handle the apparatus, and leading questions to guide the students' observations. The students followed the instructions without assistance. The teacher was instructed to keep order and offer any technical assistance necessary, but he was not to give any help in making the observations, giving information, or formulating the conclusions. The PSSC text, Physics, was the only reference book that was made available to all the students; however, they were asked to keep a record of any additional reading done in connection with the unit. The experimental part of the lesson lasted about thirty minutes. In the remaining ten minutes of the period, the students recorded their observations and conclusions in their log books.

The demonstration-experiment group followed the same lesson plan except that the experimenter did the demonstrations and asked the questions. The students were asked, at all times, to state their own conclusions. If the conclusion was inadequate, the demonstration was repeated. In the remaining ten minutes of the lesson the students recorded their observations and conclusions in their log books. The same procedure for recording any additional reading on the unit was followed for this group.

Throughout the experiment an attempt was made to control the interchange of information between the various experimental groups. This was done by enlisting the cooperation of the students. Post-experiment discussions with all the groups failed to elicit any evidence that an exchange of information had taken place. On this basis it was assumed that the amount of information exchanged between the groups was negligible, and would therefore not affect the results of this study.

III. STATISTICAL PROCEDURE

Testing the Statistical Hypotheses.

In order to compare the achievement of the various experimental groups as measured by the unit test, the questions under study were transformed into a series of null hypotheses. These null hypotheses, stated in Chapter I, were then tested by means of certain statistical tests. Acceptance of the hypotheses indicated that any differences in achievement that existed could be accounted for on the basis of chance fluctuations. On the other hand, rejection of the hypotheses indicated that the differences in achievement were not due to chance fluctuations and were, presumably, due to the operation of the experimental variable.

It was assumed that at least three factors could influence the results of this experiment significantly: differences in scholastic aptitude, knowledge of general science, and pre-experiment knowledge of the unit. Therefore, it was decided that these three factors should be controlled. Although matching the subjects in the various experimental groups on these three factors was considered, several considerations eliminated this procedure. Besides the difficulty of matching students on three variables and the consequent loss of subjects, the administrative problems of disrupting classes and adjusting the district final tests in Sc. 10 and Sc. 20 demanded that a more efficient and convenient statistical procedure be sought. It was therefore decided that an analysis of covariance would be more appropriate for analyzing the final scores. In this way, the three factors could be controlled statistically.

In order to obtain a measure of these three control variables, three pre-tests were administered: The _Henmon-Nelson Test of Mental Ability_, the _Read General Science Test_, and the _Unit Test_. The results of these tests were then used to determine whether there were any significant differences between the various groups on the three control variables; a series of t-tests were used. In using these tests, it was assumed that the variances were unequal. The method of allowing for unequal variances in using the t-test was that given by Walker.[36] The results of these tests are summarized in Chapter V.

The analysis of the pre-tests indicated that significant differences did exist between groups on two of the control variables and therefore these factors would have to be controlled. In view of these results, it was decided to test the null hypotheses by analyzing the post-test scores by means of a covariance analysis involving a control of two independent variables.

Underlying Assumptions of Statistics Used.

The appropriate statistical techniques for any experiment are determined by its design and by conformity to certain underlying assumptions. Acceptable statistical procedures require that the validity of the underlying assumptions be tested. If the assumptions are completely fulfilled, a stricter interpretation of the findings is permitted than if they are only partially fulfilled.

The first and probably most important assumption underlying any experimental study is that the samples being tested are truly representative of that population. Since the grade nine and ten grade groups used in this study were not drawn

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36. H. M. Walker and J. Lev, Statistical Inference (New York: Henry Holt and Company, 1953), pp. 157-158.

from the same grade populations of the entire province by any random process, statistical inferences regarding the achievement of the grade nine and ten groups used in this study must be restricted to the sampled grade groups only. However, insofar that the Sc. 10 and Sc. 20 students at Balmoral Junior Secondary School were representative of the provincial populations of grade nines and tens, the implications of this study may be appropriate for a more extended group of grade nines and tens.

The second underlying assumption was that the samples were normally distributed. Several investigators have shown that the F distribution is only slightly affected by a lack of symmetry and is affected by kurtosis only in extreme cases of leptokurtic and platykurtic distributions.[37] However, it was decided to test the experimental groups for normality by plotting the raw post-test scores, IQ scores, and general science scores against the cumulative percentages corresponding to these scores on probability graph paper. These graphs have been included in Appendix F.

The third underlying assumption is that of homogeneity of the variances of the groups being compared. In this experiment the Welsh-Nayer[38] test for criterion L_1, using the adjusted sum of squares, was used. Nayer computed tables of the 5 per cent and 1 per cent probability levels of L_1.

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37. Palmer O. Johnson, <u>Statistical Methods in Research</u> (New York: Prentice-Hall, 1949), p. 218.

38. <u>Ibid</u>., p. 82.

The null hypotheses that there were no significant differences between the variances of the groups being compared, were tested by computing L_1, and comparing this value with that given in the tables for the 5 per cent and 1 per cent values. If the obtained value of L_1 was greater than the 5 per cent tabled L_1 value, the hypothesis was accepted. If the value fell between the 5 per cent and 1 per cent tabled values of L_1, this finding was interpreted as being in the region of doubt; and any value below the tabled value at 1 per cent was considered to indicate the hypothesis of homogeneity of variances was rejected.

Description of the Criterion of Suitability.

Although significantly different levels of achievement may be obtained by the experimental groups, the subject-matter unit may still not be suitable for the groups in terms of some pre-determined criterion of suitability for their groups. The principle involved in using such a criterion has been established as a research technique. Washburne's[39] study in arithmetic used the arbitrary standard of performance that three-quarters of the students in a specific grade were required to obtain a mark of eighty per cent before the topic was considered suitable for that grade. The Binet scale of intelligence was constructed in a similar way. Before a test was placed at a particular age level, for example, 75 per

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39. C. W. Washburne, "Mental Age and the Arithmetic Curriculum," Journal of Educational Research, XXIII, (March, 1931), pp. 210-31.

cent of that specific age group must have passed it.

The Department of Education of this province has, by implication, set out a standard to be used as a guide in awarding letter grades in the secondary schools of this province.[40] Table X shows the details of this guide. This table provides a rough relationship between certain score intervals and the percentage of students that should obtain scores in the respective intervals. Since this criterion is used in this form, or others based on it, by some schools in this province, it was felt that the use of this criterion for determining the suitability of the unit to a particular group was warranted.

TABLE X

CRITERION FOR ASSIGNING LETTER GRADES IN THE SECONDARY SCHOOLS OF BRITISH COLUMBIA

Percentage of Students	Letter Grade	Score on Test
Top 5 per cent	A	86 - 100 %
Next 20	B	73 - 85
15	C+	66 - 72
20	C	58 - 65
15	C-	50 - 57
Next 25	D	Below 50 %

40. Province of British Columbia, Department of Education, Division of Curriculum, Administrative Bulletin for Secondary Schools: 1960. (Victoria, B.C.: Queen's Printer, 1960), p. 55.

From Table X it will be seen that, generally, 75 per cent of the students in a group are expected to obtain a mark of 50 per cent or more on a test. The Physics Revision Committee decided that this standard of suitability would be acceptable to them provided that the groups to which it is applied are equal in the factors assumed in this study to influence the performance of the groups on the unit test. If 75 per cent of any group obtained a mark of 50 per cent or more on the unit test, then the achievement of that group would be considered satisfactory.

CHAPTER V

ANALYSES OF THE DATA

In order to determine whether the mean scores of the various experimental groups on the unit test were significantly different, an analysis of covariance was carried out with scholastic aptitude, general science knowledge, and prior knowledge of the material in the unit being the factors controlled. In order to obtain a measure of these variables, pre-tests were administered, analyzed, and the results used to adjust the final test scores. The suitability of the unit to the various groups was then investigated by applying the criterion that 75 per cent of the students in a group should make a mark of 50 per cent or better.

I. ANALYSES OF PRE-TEST SCORES

<u>Analysis of the Henmon-Nelson Test Scores</u>.

Table XI presents a summary of the IQ scores obtained by the various experimental groups.

Most of the groups showed a wide range in scholastic aptitude. In one group the range was 63 IQ points, from 92-to 155. The Mean IQ scores of the various groups also varied considerably. The lowest mean IQ score was 103.80 while the highest was 133.60, a mean difference of 29.8 IQ points. The standard deviations also exhibited wide variability. The smallest standard deviation was 1.37 while the largest was 12.54. This represents a range of 11.17.

TABLE XI

SUMMARY OF IQ SCORES OBTAINED ON
THE HENMON-NELSON TEST

Group	N	Range	Mean Score	S. D.
Grade 9 (total)	60	92-155	114.86	11.29
Grade 9 (upper)	20	119-155	126.21	9.30
Grade 9 (middle)	20	113-118	115.15	1.97
Grade 9 (lower)	20	92-112	103.80	7.12
Grade 10 (total)	60	104-146	123.63	9.32
Grade 10 (upper)	20	128-146	133.60	5.60
Grade 10 (middle)	20	121-127	123.63	1.37
Grade 10 (lower)	20	104-120	114.14	5.61
Demon.-Exp.	60	92-155	119.34	12.54
Student-Exp.	60	92-142	119.23	10.44

A series of t-tests were used in order to determine whether the differences in the mean scores of the various groups were significant. In computing the observed t-values, the assumption was made that the variances were not equal. This assumption was used in adjusting the number of degrees of freedom in the computations of the t-values as described by Walker and Lev.[41] The observed t-values were then compared with the tabled values of t at the one per cent level of significance. If the computed value of t was less than

41. H. M. Walker and J. Lev, Statistical Inference (New York: Henry Holt and Company, 1953), pp. 157-8.

$t_{.01}$, the null hypothesis that the means were the same was accepted. If the calculated value of t was greater than $t_{.01}$, the null hypothesis was rejected.

Table XII presents a summary of the t-tests applied to the results of the scholastic aptitude test.

TABLE XII

SIGNIFICANCE OF DIFFERENCES BETWEEN MEAN IQ SCORES

Groups	Difference Between Means	Degrees of Freedom	t	$t_{.01}$	H_o
Grade 9-10 (total)	8.77	234	4.62	2.60	Reject
Upper 9-Upper 10	7.39	124	2.97	2.64	Reject
Middle9-Middle10	8.48	5	15.70	4.03	Reject
Lower 9-Lower 10	10.34	84	5.15	2.64	Reject
Student-Exp.-Demon.-Exp.	0.11	273	0.05	2.59	Accept

The table shows that all t-values were greater than the tabled values at the one per cent level when the appropriate degrees of freedom were used except the t-value for the methods groups. It was therefore concluded that all the groups differed significantly in scholastic aptitude except the two methods groups.

<u>Analysis of the Read General Science Test Scores.</u>

Table XIII presents a summary of the raw scores obtained by the experimental groups. The summary shows that the range of raw scores for any group was never greater than 33 points. The range for all groups was from 35 to 69. The mean scores varied from 48.50 to 59.45. The standard deviations showed that the groups did not differ greatly in variability. The smallest standard deviation was 5.94, while the largest was 8.62. The range of standard deviations was 2.68.

TABLE XIII

SUMMARY OF THE RAW SCORES OBTAINED ON THE READ GENERAL SCIENCE TEST

Group	N	Range	Mean Score	S. D.
Grade 9 (total)	60	35-66	51.47	7.95
Grade 9 (upper)	20	41-66	57.05	7.02
Grade 9 (middle)	20	35-64	49.15	7.92
Grade 9 (lower)	20	39-61	48.50	5.94
Grade 10 (total)	60	39-69	56.67	7.17
Grade 10 (upper)	20	46-69	59.45	6.28
Grade 10 (middle)	20	46-65	56.84	6.23
Grade 10 (lower)	20	39-67	53.86	8.62
Demon.-Exp.	60	35-66	52.20	7.48
Student-Exp.	60	36-69	55.95	7.95

Table XIV presents a summary of the t-tests used to test the null hypothesis that no significant difference exists between the mean scores of the various experimental groups.

The summary shows that although the mean scores obtained by the total grade groups did differ significantly, it appeared that the difference was due to the mean scores obtained by the middle ability groups in both grades. The other groups did not differ significantly in general science.

TABLE XIV

SIGNIFICANCE OF DIFFERENCES BETWEEN MEAN SCORES ON THE READ GENERAL SCIENCE TEST

Group	Difference Between Means	DF	t	$t_{.01}$	H_o
Grade 9-10 (total)	5.20	118	3.75	2.62	Reject
Upper 9-Upper 10	2.40	92	1.12	2.63	Accept
Middle 9-Middle 10	7.69	105	3.36	2.63	Reject
Lower 9-Lower 10	5.36	113	2.33	2.63	Accept
Student Exp.-Demon.Exp.	3.75	124	2.60	2.62	Accept

Analysis of the Unit Pre-Test Scores.

Table XV presents a summary of the raw scores obtained by the various experimental groups on the Unit Pre-Test. All the groups showed a fairly wide range of prior knowledge of the unit as measured by the Unit Test. The range was from 3 to 22. The mean scores, however, did not differ very much. The range of mean scores was from 9.45 to 13.30, a difference of 3.85 points. The standard deviations calculated for the various groups showed that the variability of the groups did not differ greatly. The smallest standard deviation was 2.87 while the largest was 4.22, a range of 1.35 points. It appeared that the groups were relatively homogeneous in their knowledge of the unit prior to the experiment.

Table XVI presents a summary of the t-tests used to test the null hypothesis that no significant difference exists between the mean scores of the experimental groups.

TABLE XV

SUMMARY OF THE RAW SCORES OBTAINED ON THE UNIT PRE-TEST

Group	N	Range	Mean Score	S.D.
Grade 9 (total)	60	3-19	10.80	3.52
Grade 9 (upper)	20	7-18	12.42	3.11
Grade 9 (middle)	20	7-19	10.62	2.87
Grade 9 (lower)	20	3-18	9.45	3.98
Grade 10 (total)	60	4-22	11.95	4.02
Grade 10 (upper)	20	8-22	13.30	3.98
Grade 10 (middle)	20	4-21	10.60	4.21
Grade 10 (lower)	20	6-22	11.00	3.70
Demon.-Exp.	60	4-16	10.68	3.23
Student-Exp.	60	3-22	12.07	4.22

All the computed values of t, the critical ratio, (Table XVI) were below the tabled values of t at the one per cent level of significance. The groups were therefore assumed to be equal in their knowledge about the unit before the experiment began.

TABLE XVI

SIGNIFICANCE OF DIFFERENCES BETWEEN MEAN SCORES ON THE UNIT PRE-TEST

Group	Difference Between Means	DF	t	$t_{.01}$	H_o
Grade 9-10 (total)	1.15	31	1.66	2.75	Accept
Upper 9-Upper 10	0.88	25	0.77	2.79	Accept
Middle 9-Middle 10	0.98	26	0.84	2.78	Accept
Lower 9-Lower 10	1.55	30	1.29	2.78	Accept
Student-Exp.-Demon.Exp.	1.39	35	2.02	2.78	Accept

II. ANALYSIS OF POST-TEST SCORES

Analysis of Covariance

The procedure used in the analysis of covariance was that outlined by Johnson.[42] The data related to the analysis is summarized in Table XVII.

TABLE XVII

ANALYSIS OF COVARIANCE

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	$F_{.01}$	H_o
Grade	1	27.09	27.09	1.39	6.90	Accept
Schol.Aptitude	2	32.38	16.19	1.00	4.79	Accept
Method	1	470.84	470.84	24.23	6.90	Reject
Error	105	2040.19	19.43			

All the computed values of F were less than the tabled values of F at the one per cent level of significance, except the value for the two methods groups. These results showed that a significant difference did exist between the mean scores of the two methods groups. The adjusted means for these two groups were computed by means of the method given by Garrett.[43] The adjusted mean score for the Demonstration-Experiment group was 27.69 while the mean score

42. Palmer O. Johnson, Statistical Methods in Re- search (New York: Prentice-Hall, 1949), p. 256.

43. Henry E. Garrett, Statistics in Psychology and Education (New York: Longmans, Green and Company, 1960), p. 102.

for the Student-Experiment group was 23.53.

Test for Homogeneity of Variance.

A basic assumption underlying the analysis of covariance was that the variances of the final test scores for the different groups being compared were not significantly different. This assumption was tested by computing the statistic L_1. Before L_1 was calculated, however, the sums of squares of the groups were adjusted for differences between the subjects on the three control variables described earlier in this study. The method of adjusting the sums of squares and the computation of L_1 was given by Johnson.[44] The criterion for accepting the null hypothesis of equal variances was a comparison of the computed value of L_1 with the tabled value of L_1 at the 5 per cent level of significance. If L_1 was greater than $L_{1.05}$, the hypothesis of equal variances was accepted. The data for this test is given in Table XVIII.

All the values of L_1 were greater than the tabled values of L_1 at the 5 per cent level of significance. On this basis, the assumption of homogeneity of variances was accepted.

Distribution of Scores in Relation to the Criterion of Suitability.

An analysis of the data in relation to the standard of suitability outlined in Chapter IV, namely, that 75 per

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44. Johnson, op. cit., p. 259.

TABLE XVIII

ANALYSIS OF HOMOGENEITY OF VARIANCES

Groups	Degrees of Freedom	Residual Sum of Squares	L_1	$L_{1.05}$
<u>Grade</u>			.970	.965
Nine	56	1596.65		
Ten	56	969.72		
<u>Aptitude</u>			.999	.950
Upper Third	36	876.58		
Middle Third	36	810.30		
Lower Third	36	864.96		
<u>Method</u>			.994	.965
Student-Experiment	56	971.53		
Demonstration-Exp.	56	1204.46		

cent of the students should make a mark of 50 per cent or better is given in Table XIX. The data given in the table was based on scores that were adjusted for differences between the subjects on the three control variables described earlier in this study. The method of adjusting the scores was that given by Garrett.[45]

TABLE XIX

PERCENTAGE OF SUBJECTS IN EACH GROUP MAKING A MARK OF LESS THAN FIFTY PER CENT ON THE FINAL TEST

Group		Proportion Below Fifty Per Cent
Grade Nine	- Total	17 %
	Upper Third	20
	Middle Third	15
	Lower Third	15
Grade Ten	- Total	7
	Upper Third	0
	Middle Third	15
	Lower Third	5
Method	- Demon. - Experiment	4
	Student - Experiment	20

It can be seen from Table XIX that all the groups met the criterion described earlier. On this basis, the unit was judged suitable for all the groups listed in the table.

45. Garrett, *op. cit.*

Analysis of the Log Books.

In order to determine whether any additional source of information was used by the subjects during the experiment, an analysis of their log books was made. The subjects had been asked to record this information during the experiment. No evidence could be found that they had used any additional sources of information.

CHAPTER VI

SUMMARY AND CONCLUSIONS

I. SUMMARY

Wave-motion and sound is one of the several topics that, in the opinion of the Physics Revision Committee, should be included in the secondary school science curriculum. Since no research related to the grade placement of this topic could be found, and since the provincial educational authorities are contemplating a revision of the science curriculum, it was felt that a study of this nature should be conducted. The purpose of this study was to determine the relative effectiveness of teaching a unit on wave-motion and sound at the grade nine and ten levels, using two different methods of instruction. The method called the student-experiment method was a learning procedure in which the subjects were expected to learn the material by means of experimentation in the laboratory with a minimum amount of help. Another method that was used involved the teacher as the demonstrator and the students chiefly as observers. This instruction procedure was called the demonstration-experiment method. One hundred twenty students enrolled in Science 10 and Science 20 at Balmoral Junior Secondary School were used as the subjects in the experiment.

Two questions were investigated in this study. First, do significant differences exist between the mean scores on the final test of the various grade and methods groups?

Secondly, for which of these groups is the unit suitable? As a criterion for making this decision, 75 per cent of the students in a group were required to make a score of 50 per cent or more in order for the unit to be judged suitable for that group.

In order to answer the first question, the unit test scores were studied by an analysis of covariance with scholastic aptitude, knowledge of General Science, and prior knowledge of the material in the unit being the variables controlled. Initial differences did exist between the groups on the mean scores of scholastic aptitude, and knowledge of General Science. Since the matching of subjects in the groups in order to control these differences was impractical, the method of analyzing the covariance of the scores was used.

The second question was answered by comparing the test scores of each group with the standard outlined earlier. Before the test scores were compared, they were adjusted for differences in the three factors assumed in this study to affect their performance on the final unit test. The unit was judged suitable for a group if 75 per cent of the subjects in the group made a score of 50 per cent or more.

II. CONCLUSIONS

Major Conclusions

The conclusions drawn from this study apply only to the subjects, materials, methods, and experimental conditions used in this experiment. Generalizations from the results should be made with caution.

1. There were no significant differences between the mean scores of the grade nine and grade ten groups at the one per cent level of significance.

2. There were no significant differences between the mean scores of the three levels of scholastic aptitude within the two grade groups at the one per cent level of significance.

3. Significant differences did exist between the means of the two methods groups at the one per cent level of significance. The demonstration-experiment group performed at a higher level than the student-experiment group.

4. The students in all the groups satisfied the requirement that 75 per cent should obtain a mark of 50 per cent or better on the final test. On this basis the unit was judged to be suitable for all the groups. Although all the experimental groups satisfied the criterion of suitability described earlier, the data presented in Chapter IV indicated that the sampled grade nine and ten groups were somewhat superior in terms of scholastic aptitude to the same grade populations of the entire province.

Discussion.

Although the unit was suitable for all the groups when the criterion of suitability described in Chapter IV was applied, the student-experiment group performed at a lower level than the demonstration-experiment group. A possible explanation for this difference in performance was that the subjects lacked experience in the use of the laboratory as a primary source for learning scientific material. In particular, it appeared that the students in the laboratory group lacked sufficient knowledge, skill, and experience in manipulating the scientific apparatus and in interpreting the data so that they could be reasonably sure of their conclusions. Since there were no follow-up discussions after a lesson for the student-experiment groups, the students in these groups appeared to be in considerable doubt as to the correctness of their conclusions. The demonstration-experiment group, in comparison, received lessons that were conducted primarily by the instructor.

Another factor that should be considered in accounting for the difference in performance of the two method groups was the amount of time allowed for the completion of a lesson. The basis for determining the amount of material to be studied in a science period was the amount of time required by the instructor of the demonstration-experiment group. It is possible that if the laboratory group would have had more time to become familiar with the apparatus, interpret the data and to check their conclusions by repeating the experiment if necessary, they would have performed at a higher level.

Although the instruction sheets given to the pupil-experiment groups may have been lacking in clarity and sufficient detail, no evidence could be found to support this possibility. The subjects were asked to make sure that they understood what was to be done at all times. Very few questions about the instructions were asked of the teachers supervising the laboratory groups.

As in so many instances where special subject matter is taught in a special way, many of the hoped-for outcomes could not be assessed by means of any known method. For example, it may be that the student-experiment group was superior to the demonstration-experiment group in developing an appreciation of how scientific knowledge is gained and extended. Since this study investigated the achievement of subject-matter in terms of the objectives as exemplified in the items of the test only, it was unable to measure any superiority of one group over another on achievement of any other teaching objectives.

III. LIMITATIONS OF THE STUDY

This study was designed to investigate a relatively small area of one topic in physics. The experiment was intended to serve as a guide in determining whether the unit on wave-motion and sound prepared by the Physics Revision Committee of this province would be most effective at the grade nine or ten level. In addition, evidence was sought on the relative effectiveness of teaching the material in the unit by demonstrations or student experiments. Information concerning the best method of teaching this material in relation to the abilities and interests of the students for whom the unit is intended, must be ascertained by other studies. Different methods of presenting the material, including modifications in both language, apparatus, concepts, and classroom conditions would probably alter the findings of the study. Since this study was restricted to the topic of wave-motion and sound, inferences regarding the possible grade-placement and methodology of teaching other topics in physics would not be justified. It should also be noted that conclusions drawn from the study apply only to the particular sample of students used for the experiment.

IV. PROBLEMS FOR FURTHER STUDY

This study has given rise to several problems which require further study:

1. The suitability of the unit on wave-motion and sound for grade levels below that of grade nine.

2. The suitability of the unit on wave-motion and sound for students that are below the range of scholastic aptitude used in this study.

3. The effect of modifying the material in the unit by reorganizing the sequence of concepts within the lessons as well as the order of the lessons in the unit, on student achievement at the various grade levels.

4. A study of the most effective placement of this unit in the total science curriculum.

5. The effect of teaching experience and ability of the teacher on student achievement at the various grade levels.

6. The effect of student interests, attitudes toward

science, and socio-economic background on achievement at the various grade levels.

The effect on achievement at the various grade levels of modifying the student-experiment method by using different degrees of responsibility of action on the part of pupils and teacher.

8. The effect of various kinds and amounts of follow-up of an experiment, on the achievement of the student-experiment group.

9. The effect on achievement of modifying the student-experiment method by simplifying the nature and operation of the scientific apparatus used, reducing the size of the groups doing an experiment, and increasing the amount of time allowed for the experiments.

10. The effect of various kinds and degrees of technical skills as well as experience with scientific apparatus, on achievement of the student-experiment group.

11. The effect of various degrees of training in the interpretation of scientific data on student achievement of this unit.

12. Additional studies should be conducted on the grade-placement and methods of teaching other topics proposed for the revised science curriculum.

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APPENDIX A

LESSON PLANS

LESSON 1 - INTRODUCTION

Introduction

You are all familiar with things made of matter that move from one place to another. Perhaps you have even heard that atoms and molecules are in continual motion, but are you familiar with something that isn't made of matter that moves from one place to another? Suppose for the moment that this is possible, can you imagine how you would control such a motion and put it to use?

Let's see if we can make something that isn't made of any material move from one place to another, and then observe this motion carefully.

Experiment

Set up a ripple tank as shown in the diagram (Fig. 1). Fill it to the same depth, about 1 centimeter, with water. Arrange the reflection dampers around the inside of the tank. Connect the light and lay a white piece of cardboard on the floor under the tank to act as a shadow screen. Now put several small plastic balls in the center of the tank and mark an outline of their shadows on the piece of cardboard (screen) below.

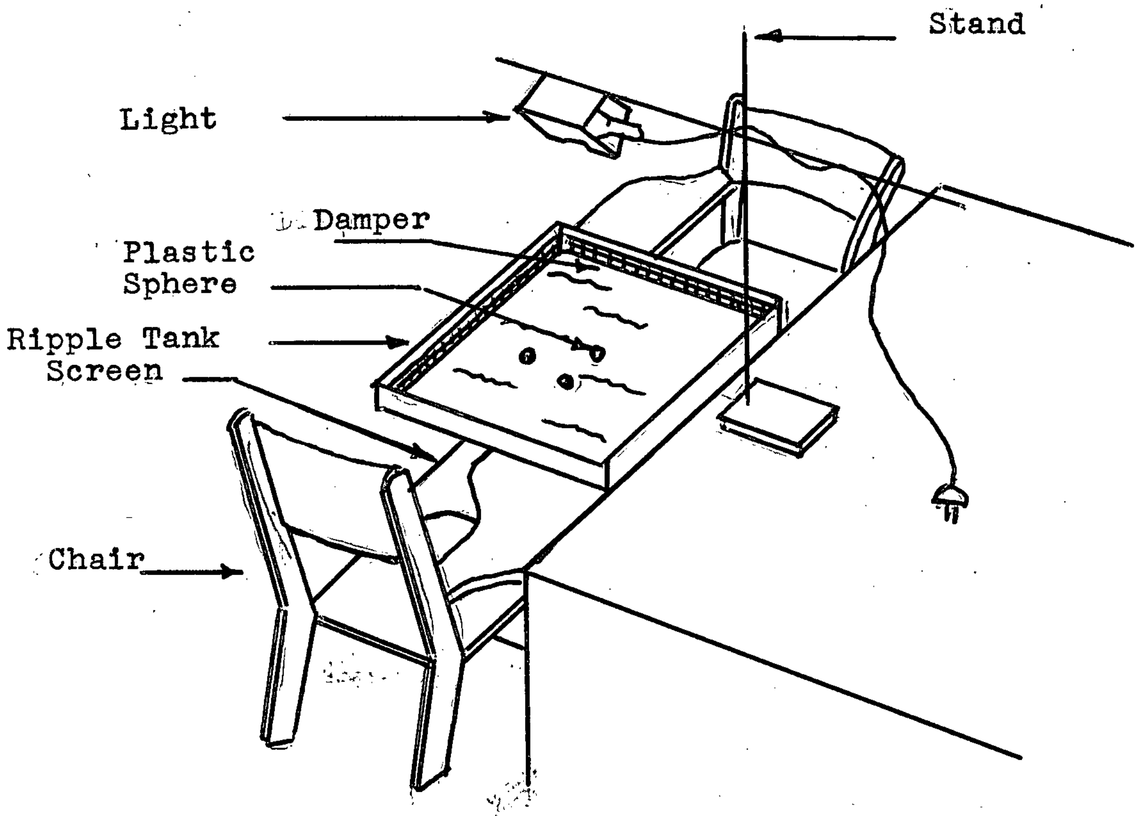


Fig. 1

Generate some waves in the tank by gently disturbing the surface of the water with a pencil as shown in Figure 2.

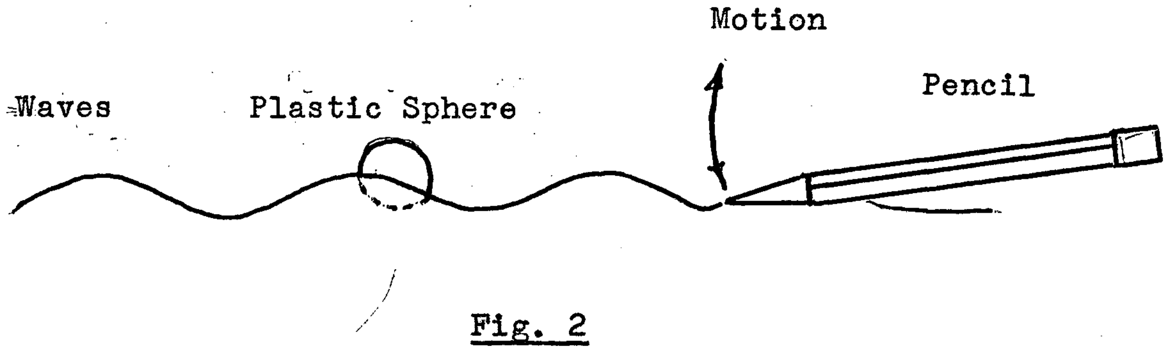


Fig. 2

Observe carefully and see if you can answer all the questions below.

1. How did the surface of the water appear before disturbing it?
2. What did the motion of the pencil in the water do to the surface?
3. Did the disturbance remain near the source (pencil)? How could you tell whether it did or did not?
4. How did the plastic spheres respond to the passing disturbances? Did the spheres change their position? (Check on the screen.) Did the spheres move at all? Can you describe this motion?

In science we call a disturbance a <u>wave</u>. We will use both these terms, disturbance and wave, <u>until</u> you are familiar with the idea that they refer to the <u>same</u> concept.

Arrange eight washers, smooth side down, on the cardboard screen so that they all touch one another (Fig. 3). Mark the middle one and put a mark on the cardboard in line with the one on the washer. Press your finger down on the first washer and strike it with another washer.

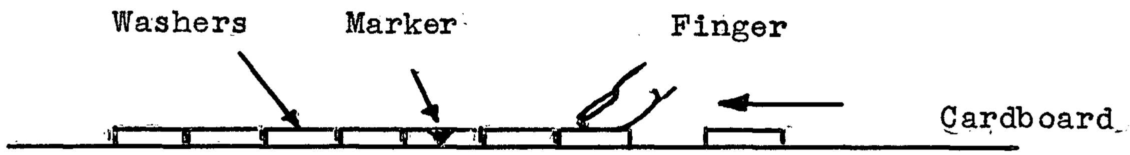


Fig. 3

What did you observe? Did any washer move? What effect did the passing of the disturbance produced by the collision have on <u>each</u> washer in the row?

A disturbance of <u>short duration</u> is often called a <u>pulse</u>. You saw the effect of a <u>pulse</u> move along a row of steel washers.

The material which transmits a wave or pulse is called the <u>medium</u>. The <u>medium</u> for the pulse you just produced was steel.

Have you ever observed a "starting-pulse" move along a long row of cars when the stop-light turns green? Why doesn't the car at the end of the line begin moving when the first car does? In which direction does the "starting-pulse" travel? What do you think would determine the speed of this pulse? Perhaps you could observe this pulse by lining up a row of steel washers to represent a line of cars. Move the first washer about five inches and then do the same to each washer in turn.

<u>Summary</u>

1. What is a wave? A Pulse? A medium?
2. What was the medium in each experiment that you did?
3. What was it that travelled when you disturbed the water in the ripple tank?
4. Was the medium carried along with the motion of a wave from one point to another in your experiments?

You have seen that it is possible for something else besides matter to travel. We call this "something" a disturbance or wave. You will find that the study of the motion of waves is basic to understanding radio, TV, radar, earthquakes and sound. In the next few lessons you will learn many interesting and helpful principles about wave motion.

<u>Assignment</u>

Record your observations and conclusions in your science notebook.

<u>A special note to you.</u>

In order to determine whether these experiments are an effective way of learning this unit, avoid discussing this lesson with <u>anyone</u> that is not in your laboratory group. If you do <u>any homework</u> or <u>extra reading</u> for this unit, record this in your science book.

LESSON 2 - WAVES ON A COIL SPRING

Introduction

Perhaps you have seen various kinds of waves before, but have never investigated them experimentally. In this experiment you will begin by studying waves along a coiled spring.

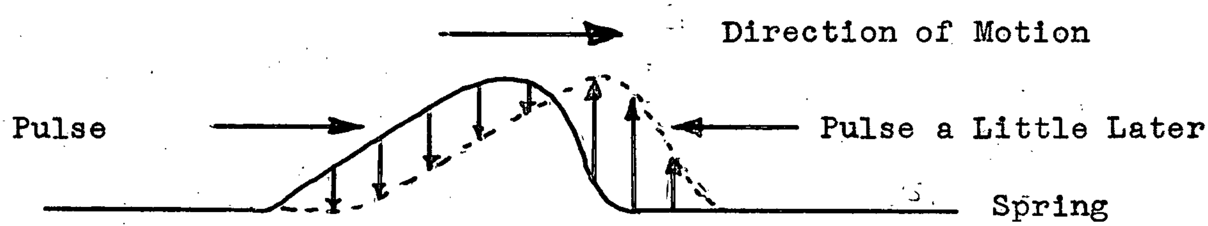
Experiment

(To be done on a smooth floor)

While your partner holds one end of the large coil spring (Slinky), pull on the other end until the coils are about 2.5 cm apart. In order to let the spring unwind as it is stretched, attach a piece of string about 2 meters long to the end coil and pull on the string until the spring is at operating length. Give the end of the spring a quick horizontal shake on the floor, and observe the shake or S-pulse move along the spring. Does the shape of the pulse change? Does the speed appear to change? Try this experiment several times with pulses of different sizes and shapes. Record your observations and conclusions.

Tie a small piece of string securely to about the middle coil of the long, thicker spring. Anchor one end to the leg of a desk, and stretch the spring as before. Take turns observing the movement of the marked coil as a pulse passes it.

Two rapidly taken photos in succession would appear as shown below:



Examine some actual photographs shown in the reference books. (Ask the instructor.) How well did your observations agree with the photos?

With the coil anchored as before, use the string to stretch the Slinky again. This time take turns producing push-pull or P-pulses on the spring by producing a quick back and forth jerk on the spring. Be careful not to release the spring! Does the speed of the pulse change as it moves along the spring? Try producing small and big P-pulses and observe their speed. Does the speed change?

Tie a piece of string securely on the middle coil of the Slinky. Produce some P-pulses, and take turns observing the movement of the coil as the pulse passes it. How would you describe the motion of the marker on the coil as a push-pull pulse passes it?

Produce alternately P-pulses and S-pulses on a stretched Slinky. Which one travels the fastest?

<u>Summary</u>

1. What are shake pulses?
2. What are push-pull pulses?
3. How do these pulses affect the medium through which they travel?
4. How does the shape and size of the pulse affect its speed along the spring?
5. How does the motion of the pulse affect its shape?
6. Which type of pulse travels the fastest?

<u>Assignment</u>

1. Record your observations and conclusions.
2. Read the information sheet on how P-and S-waves are used to study the interior of the earth.

Reading Sheet for Lesson 2

Earthquakes

Besides outbursts of volcanic activity, which eject many thousands of tons of flaming lava and enough volcanic ash to bury entire cities (the Roman city of Pompeii being the outstanding example), these subterranean disturbances often take the form of vigorous tremors in the earth's crust that are felt to a larger or smaller degree all over the world.

In the year 1775, a violent earthquake all but annihilated the Portuguese capital, Lisbon, and killed 15,000 people; the Messina, Sicily, earthquake of 1908 cost 100,000 lives; and the San Francisco earthquake of 1906 claimed an estimated 452 lives. The Japanese, who live on what amounts to a powder keg, suffer the most from quakes. The 1923 earthquake alone took a toll in Japan of 99,331 killed, 103,733 injured, and 43,776 missing. On the other hand, British earthquake casualties have so far been limited to a single person, who was killed by a falling stone during the London earthquake of 1590.

Destructive as they are, earthquakes are of great help to scientists in their study of the interior of our globe, since earthquake waves originate in some point of the earth's crust and propagate to other points on the surface of the globe through its deep interior. As we have seen above there are two kinds of waves that propagate through a continued medium:

1. P-waves (pressure or push waves) are longitudinal waves that can propagate equally well through a solid and through a fluid medium.
2. S-waves (shear or side waves) are transverse waves that can propagate through solids but not through liquids.

When an earthquake wave from a distant disturbance arrives at the surface of the earth, the motion of the ground in the case of P-waves will be in the direction of propagation; while in the case of S-waves this motion will be perpendicular to it. This permits us to distinguish between P- and S-waves by registering the movements of the ground by means of very sensitive instruments known as seismographs.

Let us consider now what would be observed by seismic stations scattered all over the world when a sufficiently strong earthquake originates in some point of the earth's crust. Figure 1 shows the propagation lines of the disturbance originating in point A of the crust. At stations I, II, and III located within 100 degrees from the center of the disturbance, both P- and S-waves are observed, which proves that the material of the earth possesses the property of an elastic solid (capable of experiencing a shear) up to very great depths. This fact is the basis for the statement made above to the effect that, although the deep-lying rocks are heated well above their melting point, they retain the properties of an elastic solid in respect to rapid deformations such as those caused by a propagating S-wave.

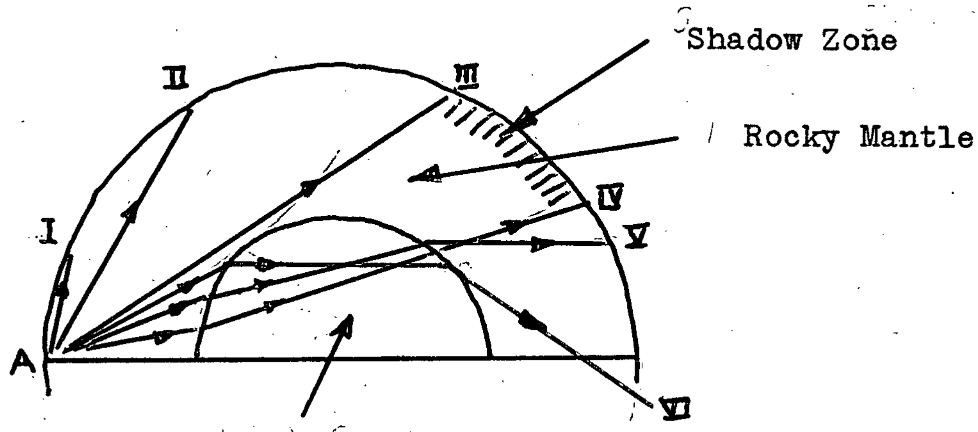


Fig. 1

The amazing point about earthquakes is that beyond a distance of 100 degrees from the center of the disturbance, there always exists a ring-shaped "shadow zone" within which the earthquake waves are not felt at all. Movements of the crust again become noticeable within 35 degrees of the antipode point (i.e., the point directly opposite the origin of the earthquake), but only those produced by the P-waves. To explain this unusual fact, seismologists, i.e., scientists who study earthquakes, had to assume that the central part of the earth is occupied by a core that is in a liquid state and thus cannot carry S-waves. With this assumption, the existance of the "shadow zone" can be easily understood by inspecting the rays of earthquake waves shown in Fig. 1. Due to a rapid increase of pressure and density with depth, the velocity of seismic waves (both P and S) also increases and causes the propagation lines to bend slightly towards the surface. Thus, the waves arriving at station III, after passing very close to the surface of the molten core, are the last ones that still propagate all the way through the plastic material of the rocky mantle. The rays that propagate deeper inward will hit the surface of the core, and while S-waves will not be able to propagate beyond this point at all, P-waves will be refracted as shown in Fig. 1. After the second refraction at the exit point from the liquid core, the P-waves will finally arrive at the surface much closer to the antipodal point and thus produce a ring-shaped shadow zone.

The knowledge of the propagation velocities of seismic waves at different depths under the surface enables us to get information concerning the material from which the interior of the earth is formed. It was found in this way that our globe has an onion-like structure consisting of a large number of concentric shells. Under a comparatively thin layer of granite rocks, which form the continental massifs, is located a layer of heavier basalt rocks. As it was indicated above, this basalt material below the depth of about 50 km is heated above its regular melting point but remains in a plastic state because of high pressure. The extensive studies of seismic waves propagating through the earth's interior led to the discovery of other layers with interfaces located at depths of 400 and 960 km. The most interesting discontinuity occurs, however, at the surface of the central core, 2,900 km under our feet, or at 60 per cent of the earth's radius from its center. At this interface, the density, which steadily increases (because of compression) from 3.0 at the surface to about 5.5 at this interface, jumps suddenly to 9.5, indicating that the core is composed of some considerably denser material. It is generally agreed that the core of the earth lying within this interface is formed almost exclusively by molten iron with a small admixture of chromium, molybdenum, and nickel. The temperature of the core is estimated to be at least 2,000 degrees C, which is considerably higher than the melting point of iron (1,535 degrees C).

LESSON 3 - SUPERPOSITION OF WAVES

Introduction

When two material objects, such as two aeroplanes, collide, their motion is completely altered. What do you think would happen if two waves which do not consist of matter collide? Let's try it experimentally.

Experiment

Stretch the Slinky about 5-6 meters with a person holding each end of the spring. Both partners should now flick their wrists at the same time; two pulses will travel towards each other on the spring. Did the pulses knock each other out as they collided? What was the shape of the combined pulse as they passed through each other? (Did it resemble either of the original pulses?) What did the pulses look like after they had passed through each other?

You can determine the height of the combined pulse as they pass through each other by moving your hand a measured distance as it generates the pulse. A third partner can mark with chalk the largest pulse on the spring when the pulses meet.

Examine some actual photos of two pulses passing through each other in the reference books. (Ask the instructor.) Read the related section called Superposition: Pulses Crossing. How well did your observations compare with the photos and description in the book?

Summary

1. What happens when two waves meet each other on a spring?
2. How can the shape of the pulses be predicted while they are passing through each other? What principle is applied here?
3. What shape and size do the pulses appear to have after passing through each other?

Assignment

Record your observations and conclusions.

LESSON 4 - REFLECTION AND TRANSMISSION

Introduction

In addition to waves passing through each other, have you observed what happens to a pulse when it reaches the end of the spring? Suppose we tied a different spring to the end of a Slinky, what would a pulse do when it arrived at the place where the two springs meet? Let's start by checking on what happens when a pulse arrives at the end of a Slinky.

Experiment

Attach one end of the Slinky firmly to a table or desk leg. Grasp the spring in the middle, and stretch the section from the fixed end to a length of about 2-3 meters so that the coils are about 2.5 cm apart. Again, with a horizontal flick of the wrist, send a shake pulse along the spring. What happened to the pulse as it reached the fixed end? On what side of the spring did the pulse return? Is the shape and speed of the reflected pulse different that it was before reflection?

Hook the long, heavy spring to the handle at the end of the Slinky. Tie the end of the long spring to some stationary object such as a desk. Pull on the other end of the Slinky and stretch both springs until the coils of the Slinky are about 2.5 cm apart. Use only about 3 meters of the Slinky. Generate some shake pulses on the Slinky. What happened to the pulse when it reached the heavy spring? How does the shape, position, and speed of the reflected part of the pulse compare with the transmitted part? Now send the pulse from the heavy spring to the light one and repeat the observations.

Tie a piece of light string, at least 2½-3 meters long, on to the handle of one end of the Slinky. Stretch the spring with the string. Generate shake-pulses on the Slinky. The string is a much lighter medium than the spring. How did the reflected part of the pulse appear (shape, position, speed)? The string makes the end of the spring act as a free end.

Summary

1. How does the pulse reflect at the fixed end of a spring?
2. What happens when a pulse, travelling in a light spring (low density), meets a denser medium such as a heavy spring?
3. What happens when a pulse, travelling in a medium such as a Slinky, meets another medium that is less dense?

Assignment

Record your observations and conclusions.

LESSON 5 - STANDING WAVES

Introduction

You have seen that when a pulse, travelling along a spring, reaches the end where the spring is fixed, it reflects. Suppose that a train of similar pulses are moving along a spring, and that the reflections of these pulses are in step or synchronized with the new pulses being generated. What effect would this synchronization of pulses have on the spring? What would happen if the pulses got out of step with the new pulses being generated? Let's try this out in the laboratory and see if we can answer these questions. You will see later that this lesson has wide application not only in producing music, but even in atomic physics.

Experiment

While your partner holds one end of the long thick spring firmly, stretch the spring about 4-5 meters (not too much). By means of small, repeated, horizontal flicks of the wrist, generate a train of similar pulses. Adjust the frequency of your hand movements until the reflections are in step with the pulses that you have generated. The motion of the spring should appear as in the diagram (Fig. 1) below. Ask your instructor for help if you need it.

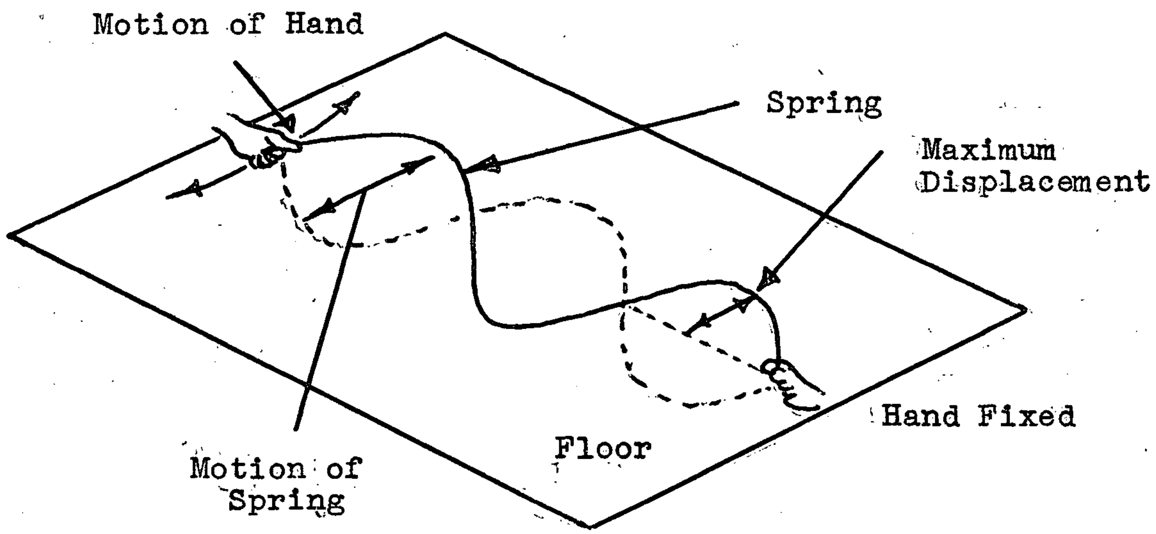


Fig. 1

Were all the points along the spring in horizontal motion? How many points were there that appeared to have almost no horizontal displacement? How many points were there that were undergoing maximum displacement? Is the maximum displacement of the pulses more or less than the displacement of the pulses before they were in step with the reflections?

Observe the travelling motion of the pulses before they are synchronized with the reflections. Do the pulses appear to travel when they are synchronized with the reflections?

You have been observing standing waves on a spring. Standing waves are not really stationary; the generated pulses are travelling along the spring at the same time as the reflections are, but they are travelling in opposite directions. At certain points on the standing wave, the spring is undergoing maximum displacement and at other points the displacement of the spring is zero. Points of maximum displacement of the spring are called antinodes while points of zero displacement are called nodes. The maximum displacement of an antinode is called the amplitude of the pulse. (Figure 2)

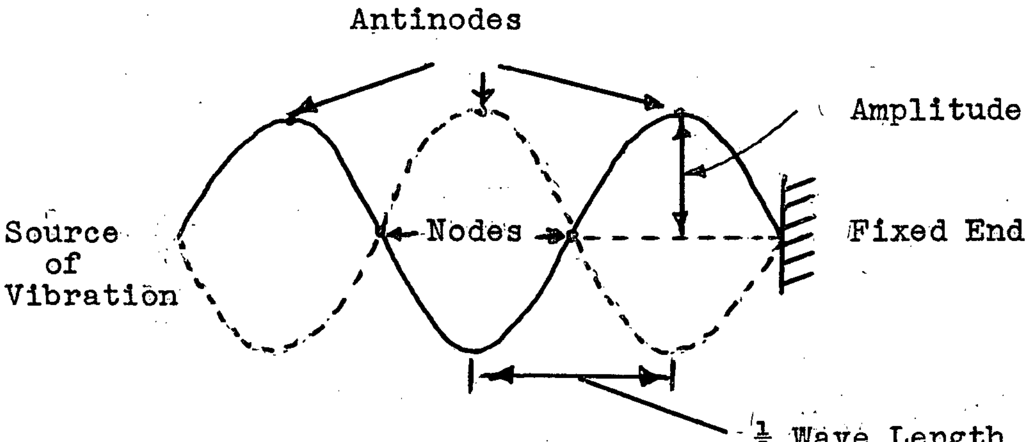


Fig. 2

Characteristics of A Standing Wave

Repeat the production of standing waves. Try producing standing waves with a different number of nodes. Is it possible to have an even number of nodes between the ends of the spring? Odd number? More or less than a whole number of nodes? The wave length of a standing wave is twice the distance between two antinodes or nodes. Measure the length of the stretched spring and then count the number of nodes or antinodes and estimate the wave length of a standing wave on the spring.

$$\text{Wave length} = \frac{\text{Length of spring}}{\text{Number of wave lengths}}$$

Try this with standing waves that have a different number of nodes.

Summary

1. How is a standing wave generated?
2. Why is it called a standing wave?
3. What are points of maximum displacement called? Zero

displacement?

4. What does amplitude mean?
5. How many nodes are possible between the two fixed ends of a vibrating spring?
6. What does a wave length mean?
7. How can the wave length of a standing wave be determined?

Assignment

Record your observations and conclusions.

LESSON 6 - WAVES IN TWO DIMENSIONS

Introduction

So far we have been studying the motion of waves that were confined to a rope or spring, that is motion in one dimension. If we produce a wave in a medium where it has more freedom, how will it appear? A water surface has two dimensions, length and width. Let's see what waves will look like if they can travel in two dimensions.

Experiment

Set up the ripple tank as you did in Lesson 1. Fill the tank to the same depth (approximately 5 - 7 mm). Let a drop of water fall into the middle of the tank from the end of a sharp pencil. What shape was the pulse? How did this pulse move away from the point where the drop fell? Did all parts of the pulse travel at the same speed? How could you tell? You have seen the shape and motion of a pulse produced by a single point of disturbance.

What kind of wave pattern would you see if two point sources of disturbance were used at the same time? Set up the two-point vibrator as shown below in Figure 1:

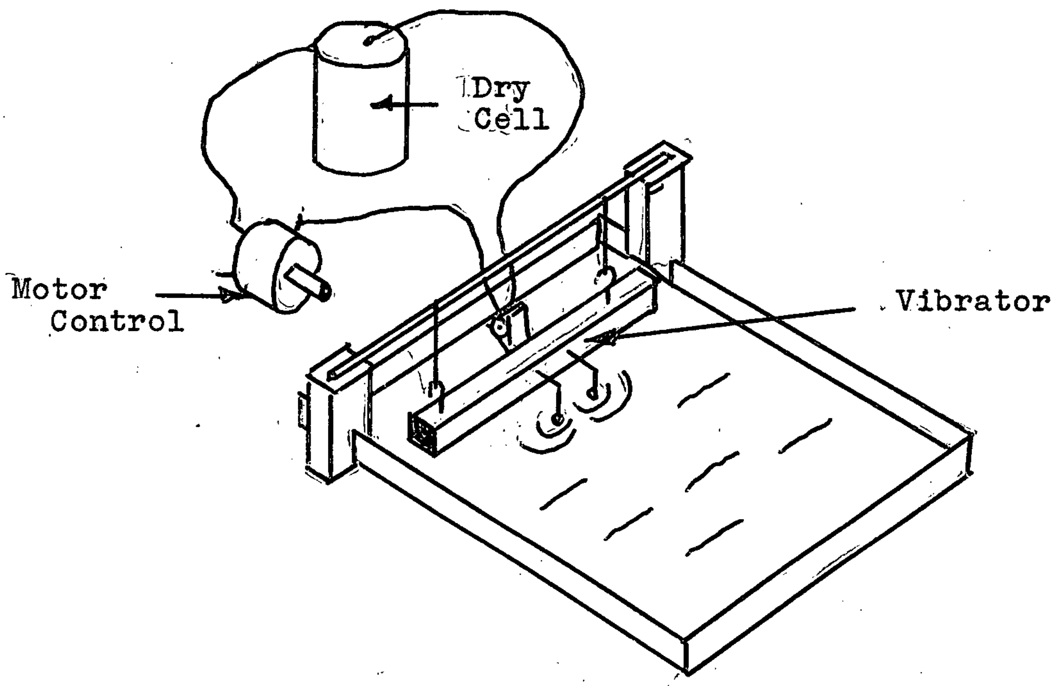


Fig. 1

Ask your instructor to help you set up the vibrator.

Set the motor at slow speed and observe the wave pattern being produced. The pattern appears rather complicated. However, if these waves act like other waves, we could predict or explain the resulting pattern by the Principle of Superposition. Can you tell where the waves have cancelled or reinforced each other?

Make a multiple point source as shown in Figure 2 below, and generate waves in the tank by dipping it in and out of the water.

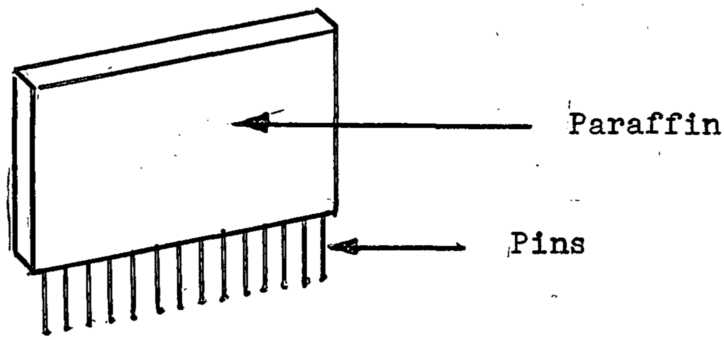


Fig. 2

Observe the shape of the waves. What does the wave pattern look like a short distance ahead of the middle part of this source? If you had used many more pins, very close together, and all in a straight line, what kind of wave pattern do you think such a device would produce?

Remove the multiple point source and just use the wooden bar as a vibrator as shown below:

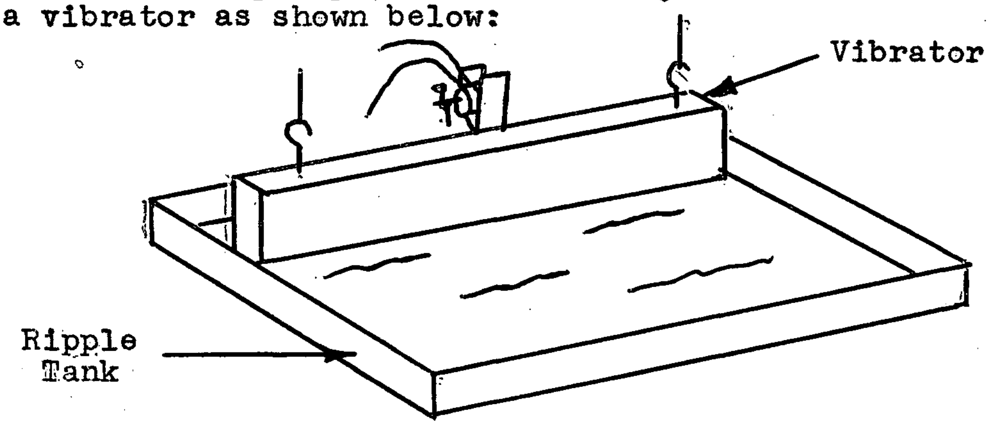


Fig. 3

What is the shape of the wave pattern produced by the straight wooden vibrator? How does this wave pattern compare with the wave pattern produced by the multiple point source? What scientific principle does this comparison of wave patterns suggest? This principle was suggested by Huygens over 200 years ago and has turned out to be extremely useful in the study of light.

Summary

1. What kind of wave pattern does a point source produce?
2. At what speed do all points along this pulse travel?
3. What kind of a wave pattern does a multiple point source, all points in a straight line, tend to produce?
4. How does the multiple point source pattern compare with the waves produced by a straight solid piece of wood?

Assignment

Record all observations and conclusions.

LESSON 7 - REFLECTION OF WAVES

Introduction

You will recall how a pulse travelling along a spring reflected from the fixed end of the spring. In what manner will waves in two dimensions reflect when they meet some change in the medium such as a barrier in the water? You can study the reflection of these waves by means of a ripple tank.

Experiment

Set up a ripple tank as in the last experiment. Remove the dampers. Tap one end of the tank or stamp your heel on the floor in order to generate straight waves in the tank. At what angle to the generated waves do the reflected waves seem to move?

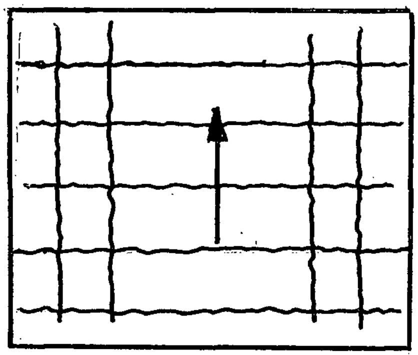


Fig. 1

Replace the dampers and use the straight-wave generator to produce low-frequency waves.

Set two blocks of paraffin in the water to act as a reflecting surface for the waves. Set the blocks at about 45 degrees to the incoming or incident waves.

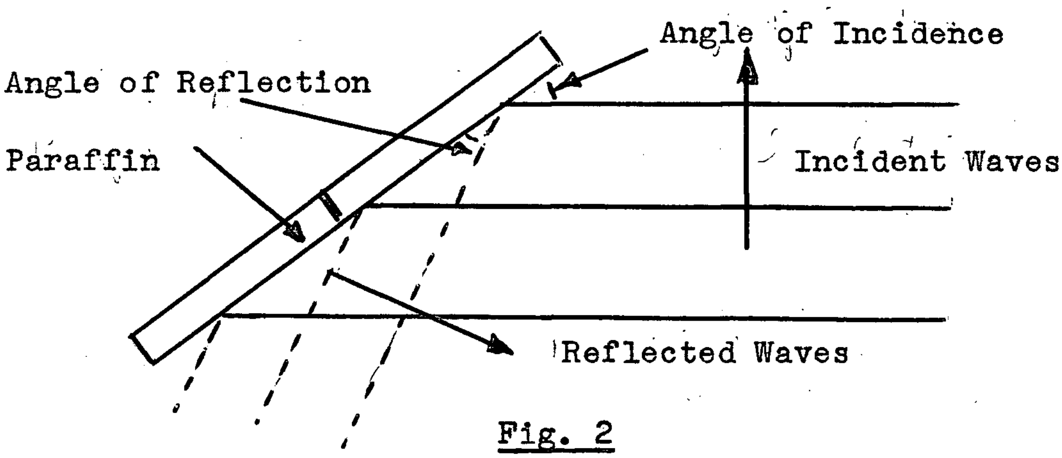


Fig. 2

Mark on the screen an outline of the blocks, and then, with a ruler, mark the incoming and reflected waves. Measure the angle of incidence and the angle of reflection. Repeat this experiment for different angles of incidence. What seems to be the rule that would give the relationship between the angle of incidence and the angle of reflection?

Using a pencil, generate circular waves at various points in the tank. Begin near the end of the tank, and then gradually move away towards the middle. Observe how the circular waves reflect from the end of the tank when produced close to it, and then from points farther away. What is the shape of the reflected waves? Where do the reflected waves appear to have their origin? Since this origin is not real, it is said to be a virtual origin. Images in a mirror are also virtual, that is, they are not real.

Replace the paraffin blocks by a length of tubing bent to form a pear-shaped curve called a parabola. (The mirrored surface inside a car headlight is parabolic in shape.)

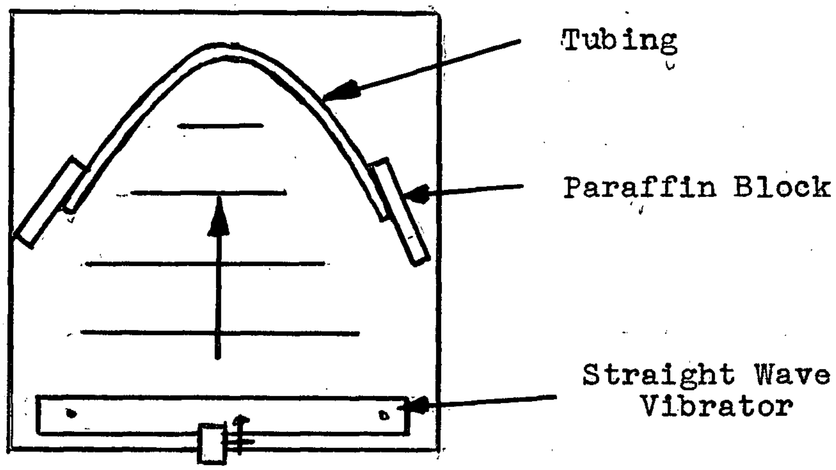


Fig. 3

Generate some straight waves and observe how they are reflected from the tubing. What shape do the reflected waves have? Notice that the reflected waves seem to come together or focus towards a point in front of the tubing. This point is called the focus or focal point.

Using a pencil, produce circular waves at the focus of the parabola. What shape do the reflected waves have?

Summary

1. How does the angle of incidence compare with the angle of reflection for straight waves reflecting from a smooth, straight barrier?
2. How do circular waves reflect from a smooth, straight

barrier?
3. What does a virtual image mean?
4. What is a parabola? Focus?
5. How do straight waves reflect from a parabola?
6. How do waves generated at the focus of a parabola reflect from the parabolic surface?

Assignment

Record all observations and conclusions.

LESSON 8 - DIFFRACTION OF WAVES

Introduction

In this lesson you will investigate one more important property of waves, this is, how waves behave when they pass through openings or meet obstacles in their path.

Experiment

Set up the ripple tank for generating straight waves. Place a small paraffin block (5 cm long) about 10 cm from the straight wave generator. Generate a train of waves of long wave length, that is longer than the length of the block. How do the waves appear behind the block? Does the block cast a sharp shadow?

Decrease the wave length gradually by speeding up the motor. The wave lengths should be decreased to less than half the length of the block. How do the waves appear behind the block? Does the block cast a sharper shadow this time?

The bending of waves around an obstacle is known as diffraction. What principle seems to determine the amount that waves diffract around an obstacle? Check your conclusion by repeating the experiment with different wave lengths.

Arrange two paraffin blocks so that there is an opening between them of about the same size as the obstacle was.

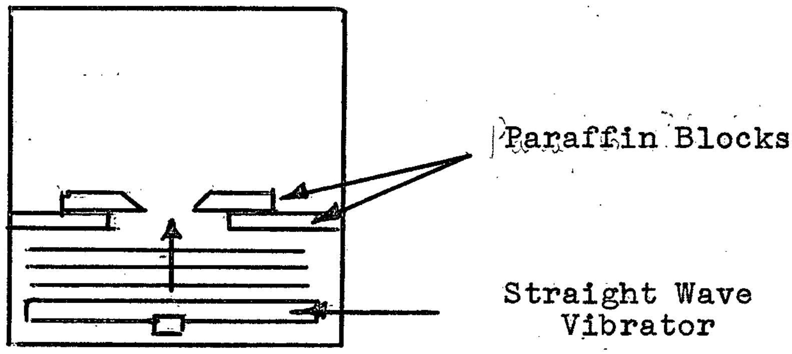


Fig. 1

Generate some straight waves. Adjust the size of the opening so that it is larger than a wave length, and then smaller than a wave length. How do the waves appear behind the slit when the opening is very small? Large? The bending of the waves, you will recall, is called diffraction. What principle seems to determine the amount that waves will diffract when passing through an opening? This time keep the opening the same and, by adjusting the speed of the motor, produce long and short straight waves. How does the wave pattern behind the opening appear? What seems to be the rule for diffraction in this case?

Summary

1. What is meant by diffraction?
2. What is the relationship between the amount of diffraction, the size of the obstacle, and the wave length?
3. What is the relationship between the amount of diffraction, the size of the opening, and the wave length?

Application

A harbour has a sea-wall at its mouth. If the sea-wall is long enough, that is, the opening through which the waves and ships pass is small, short ocean waves will pass through the gap but only affect the area in direct line with the gap. Ocean swells are long waves. How will these waves affect the boats in the harbour?

Assignment

Record all observations and conclusions.

LESSON 9 - SOUND: A WAVE PHENOMENON

Introduction

You have been investigating waves produced on springs and the surface of the water in a ripple tank. In this lesson you will begin an investigation into the phenomenon of sound. How is sound produced? What determines the pitch of sound? How does sound reach our ears?

Experiment

Lay a ruler on the table so that part of it extends over the edge. Hold the ruler down firmly, and pluck the end as shown below:

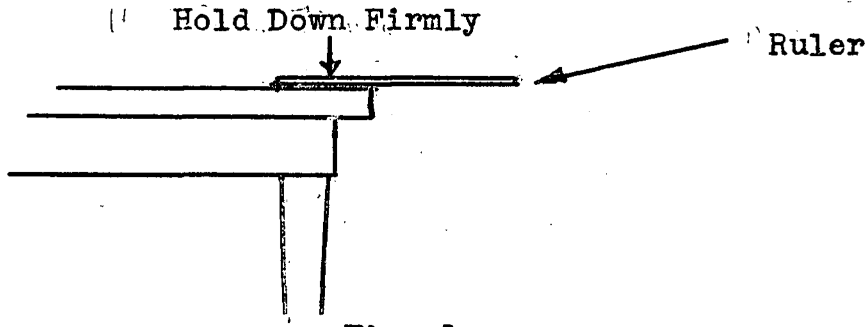


Fig. 1

Listen to the sound. What caused the sound? Shorten the part of the ruler extending over the edge of the table. Pluck the ruler and listen to the sound. How do the sounds compare in "highness" or "lowness"? Do this again, but this time observe how fast the different lengths of the ruler vibrate. How is the frequency of vibration related to the "highness" or "lowness" of the sound? The "highness" or "lowness" of a sound is called the pitch. You have been investigating how the pitch of a sound is related to the frequency of the vibrating ruler.

Take a tuning fork and strike it with a rubber hammer(a rubber stopper on the end of a pencil). Listen to the pitch. Compare this pitch with that of other tuning forks of different sizes. (Exchange forks with somebody else.) How does the size of a vibrating object seem to be related to the pitch?

Set up a Fisher Burner and adjust it for a strong flame. Carefully lower a large cardboard or metal tube directly over the flame. Lower the tube so that the flame is inside the tube briefly. (Be careful not to ignite the inside of the cardboard tube.) Listen to the sound. Repeat this with a metal tube fitted with a piece of wire gauze inside. While the sound is coming from the tube, tilt the tube into a horizontal position, and then to a vertical position. What effect did tilting the tube have on the sound? Does this suggest what was producing the sound?

Compare the pitch of the sound from your tube with some of the others in the group. How does the pitch of the sound seem to be related to the construction of the tube? Does this give more evidence as to what was vibrating in order to produce the sound? Why did the sound fade away? How could the sound be kept going? Since you could hear the sound coming from a source at some distance from your ears, how do you suppose the sound could reach your ears?

Set up the experimental apparatus as shown below:

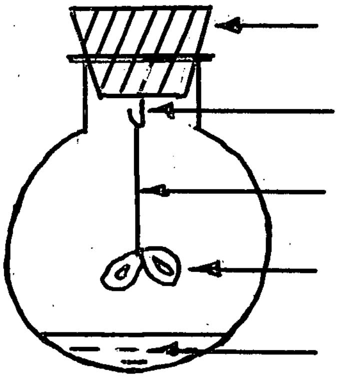


Fig. 2

(CAUTION: The jar will crack if heated or cooled too quickly.)

Boil the water in the flask for a minute or two so that the steam can drive out the air. Turn off the heat and insert the bell. Screw the lid on the jar, or cover the flask with rubber stopper. Listen to the sound of the bells at various times during the cooling process. After the jar has cooled, open it and allow the air to enter. Seal the jar again (with the air inside), and compare the loudness with when it had very little air in it. Does this suggest how sound reaches our ears?

Summary

1. What is the basic cause of sound?
2. What determines the pitch of sound?
3. How can a sound be kept going?
4. How does sound reach our ears?

Assignment

Record your observations and conclusions.

LESSON 10 - SOUND WAVES

Introduction

You have seen that sound is caused by the vibration of some source and that a medium such as air is required in order to hear it. In this lesson you will investigate much more direct evidence of the wave nature of sound.

Experiment

Set up standing waves in a column of air as indicated below:

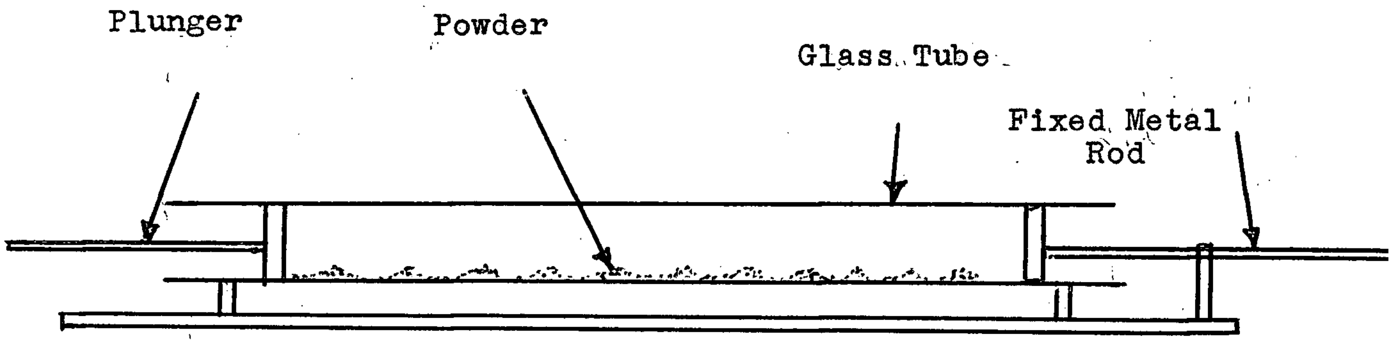


Fig. 1

Set the metal rod into vibration by drawing a resined cloth smartly at the free end. You should hear a high piercing sound. The rod is now elongating and shortening at a very high frequency. This rapid change in the length of the rod produces push-pull pulses in the air column inside the tube. Move the plunger back and forth in small steps until these pulses are synchronized with the reflections. The resulting standing wave in the air column disturbs the powder and arranges it into a train of little heaps or crests. These heaps mark the antinode positions. How is the distance between two heaps (antinodes) related to the wave length of the standing wave? Check your science book if you have forgotten.)

Measure the distance between four heaps and estimate the wave length of the standing waves. The speed, wave length, and frequency of a train of similar waves are related by the formula $v = fL$. Assume that the sound waves in the air column are travelling at a rate of 344 meters/sec., at room temperature. What was the frequency of the sound waves in the tube? (If $v = fL$, then $f = v/L$.) (This is also the frequency of the metal rod.)

Rearrange the powder in the tube and repeat this experiment several times. In each case estimate the frequency as indicated above. How well do your calculations agree?

Summary

1. What was the evidence that sound is a wave phenomenon?
2. How are standing sound waves produced?
3. How is the wave length of a standing sound wave determined?
4. What is the speed of sound waves in air at room temperature?
5. How can the frequency of a standing sound wave be computed?

LESSON 11 - THE SPEED OF SOUND WAVES

Introduction

In the last lesson you were asked to assume that the speed of sound waves is about 344 meters/sec. at ordinary room temperature. How can this speed actually be measured?

Experiment

Set up the apparatus as shown below:

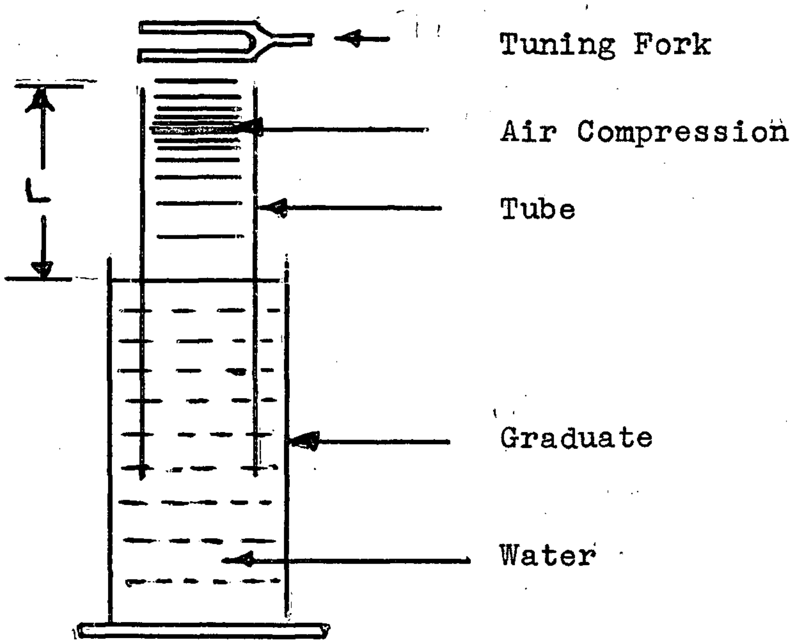


Fig. 1

Set the fork vibrating by striking it with a rubber hammer (rubber stopper on a pencil), and hold the vibrating fork above the glass or paper tube as shown. Listen carefully to the sound coming from the inside of the tube. Raise and lower the tube in the water while the fork vibrates above it. You should be able to find positions at which the loudness of the sound increases.

Find the shortest length at which the sound of the note that the fork produces becomes louder. Does this note become louder at other positions? When the sound coming from the tube becomes louder, the sound waves reflecting from the water at the bottom of the tube are in step with the vibrations of the fork. The reflected waves reinforce the new waves being produced by the fork. This reinforcement increases the amplitude of the sound waves, and produces the effect of a louder sound in the ear. When the vibrating fork and air column are in step, they are said to be in resonance.

At resonance a standing wave exists in the tube. You will remember that the maximum displacement or amplitude of a standing wave is always greater than the amplitude of the waves being produced before they are in step with the reflections.

The shortest air column at which resonance occurs has sound waves that have a wave length of 4 times the length of the air column, that is,

$$\text{wave length} = 4\text{ L}$$

Measure the length of the shortest air column at which resonance occurs, and calculate the wave length. Using this wave length, calculate the speed of the sound waves in the air column. (Remember that speed = frequency x wave length.) The frequency of the fork is stamped on it.

Repeat the calculation of the speed of sound in air by using different tuning forks. (Exchange forks with other groups.) How well do your calculations agree?

You are also able to get resonance with other lengths of the air column, as you found. It can be shown that the next shortest air column at which resonance occurs has sound waves that have a wave length of 4/3 of the length of the air column, that is,

$$\text{wave length} = \frac{4\text{ L}}{3}$$

When you get the fork that has a frequency of 512 vib/sec. of 2048 vib/sec., measure the second shortest air column at which resonance occurs, amd calculate the wave length. Now calculate the speed of the sound waves as you did before. How well does this calculation agree with the others? Average all your calculations for the speed of the sound waves.

Summary

1. What does resonance mean?
2. What is the wave length of the shortest air column at which resonance occurs?
3. What is the wave length of the next shortest air column at which resonance occurs?
4. Theoretically, the speed of sound waves, at room temperature (20° degrees C.) is close to 344 meters/sec. How well does your average agree with this?

Assignment

Record your observations, calculations, and conclusions.

LESSON 12 - THE DIATONIC SCALE

Introduction

Music is an interesting sound phenomenon. Musical instruments are essentially machines for imparting energy to the air in the form of waves. They generally consist of two parts: a generator which produces the sound, and a resonator which makes the sound louder. Can you identify these parts on some musical instrument?

Music itself is made up of melodies. You may think that a musician has a countless number of sounds (notes) to choose from in writing music. However, experience has shown that the most pleasing melodies are constructed from a small group of notes called a scale. Why do you think this is so? It is a rather interesting fact that the notes of a scale have to be related by a rather precise mathematical rule in order to be pleasing to the ear. Let's see if we can find the rule.

Experiment

Press a pencil on the 100 cm mark of one of the sonometer strings. Pluck the string, and listen to the sound of the note. This note is C, the first note of the scale, C,D,E, F,G,A,B,C^1 marked on the box. (C^1 is the next note called C above the first C.) How many notes apart are C and C^1, including these two notes? These notes are said to be an octave apart. The ear recognizes these two notes as a repetition, one of the other, even though they differ in pitch.

Now play the following notes and carefully compare the lengths of the strings which give each note - C, C^1, G, and E to the length of the string sounding C (100 cm). To do this set up the ratio:

$$\frac{\text{Length of string producing C}}{\text{Length of string producing other note}}$$

Adjust each term in the fraction in such a way that you will get the smallest possible numbers in both the numerator and the denominator, that is, try to get the simplest fraction that will approximate the ratio.

Example: $\text{Ratio} = \frac{C}{G} = \frac{100 \text{ cm}}{66.75 \text{ cm}} = \frac{99}{66} = \frac{3}{2}$

What is the simplest ratio of the lengths of the string producing C and C^1? What is the rule governing octaves? You could check this rule by taking any other note in the scale as a key-note and then comparing the length of the string producing this key-note with a note an octave above it.

This kind of experiment was probably performed by Pythagoras around 500 B.C. If the length ratios are simple fractions, the notes form what is called the natural or diatonic scale. How well do your length ratios agree with those given below?

Note:	C	D	E	F	G	A	B	C^1	
	$\frac{1}{1}$	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{17}{8}$	$\frac{2}{1}$	Length ratios

Diatonic Scale

These ratios also express the rule for obtaining the pitch of any note in the diatonic scale. For example, the frequency (pitch) of the note D is 9/8 that of the key-note C. The pitch of A is 5/3 that of C, and so on.

If the key-note C has a frequency or pitch of 256 vibrations/sec., calculate the pitch of each note in the diatonic scale.

Summary

1. What is an octave?
2. How are the frequencies or pitch of each note in the diatonic scale related to the key-note C?
3. If two notes, an octave apart are played on the same string, how do the lengths of the string producing the notes compare?

Assignment

Record your observations, calculations, and conclusions.

LESSON 13 - THE QUALITY OF SOUND

Introduction

What makes the instruments of an orchestra sound differently even if they are all playing the same note? Let's investigate one important reason for this difference.

Experiment

Set up the apparatus below:

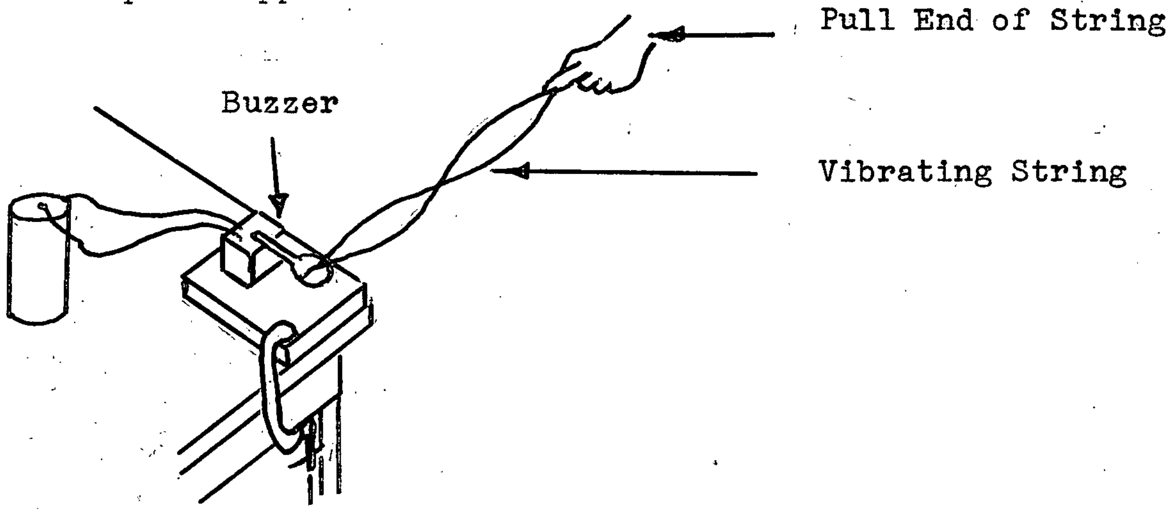


Fig. 1

Set the buzzer into operation, and by pulling gently on the other end of the string, produce standing waves with one, two, three, etc., antinodes. What is the rule for the number of nodes or antinodes that can be produced on a vibrating string?

When a vibrating string vibrates so that the standing wave has only one segment or antinode, it is said to be producing its fundamental note or first harmonic. If the standing wave has two segments or antinodes, it is producing its second harmonic, and so on. As you have seen, only a certain number of harmonics are possible on a string fixed at both ends.

You probably couldn't hear the sound being produced while the string was producing the harmonics. We can make the sound accompanying the harmonics audible by using a stringed instrument.

Using a sonometer, or other stringed instrument, pluck or bow the heaviest string lightly near one of the fixed ends. Put 8 small paper riders on the string. What happened to the riders? Why? The string, when set vibrating is now producing its fundamental note or first harmonic.

Put your finger lightly on the middle of the string. This point now becomes a node. Pluck or bow one of the halves. The string is now vibrating in two segments, that is, it is producing a second harmonic. How does the sound compare with the fundamental note that you played before? If the fundamental was the key-note of a diatonic scale, what note of the scale is the second harmonic?

Now place the finger lightly over a point which is 1/3 of the way along the string. This point becomes a node. Set the string into vibration between the point where your finger is and the fixed end. The string is now producing its third harmonic. Can you find the other node with paper riders? How does the third harmonic sound when compared to the fundamental? Can you judge which note of the diatonic scale this note is? Try humming the notes of the diatonic scale beginning with the fundamental note of the string as the key-note C. Hum the notes of the scale until you hum a note that sounds like the third harmonic.

Try to get other harmonics by lightly touching the string at 1/4, 1/5, etc. of the length of the string. Can you judge what note on the diatonic scale these harmonics give? The harmonics you have produced form a sequence of notes that a wind instrument, such as a trumpet, can produce if it has the same fundamental, and no keys are used. Not all harmonics correspond to the notes of the diatonic scale. The seventh harmonic is an example of this.

Different instruments have different harmonic structures because they can vibrate differently than a string can. The quality of the sound of an instrument depends upon the harmonic structure of the sound produced. The quality of the sound of a stringed instrument is largely determined by the fact that it can only produce certain harmonics because it is fixed at both ends.

Ask your instructor to demonstrate to you, electronically, the different wave forms produced by different instruments because of the different harmonics that they produce. Compare the qualities of the sound produced by these instruments.

About the Test

You can prepare for the test by looking through your record of the experiments in your science book. Do this thoughtfully. Please avoid discussing the material with students who are not in your laboratory group.

APPENDIX B

THE UNIT TEST

Experimental Directions for Administering

ACHIEVEMENT TEST
ON
WAVE MOTION AND SOUND

GENERAL DIRECTIONS TO THE EXAMINER

1. Before attempting to administer this test the examiner should read the specific directions governing the administration of the test.

2. The usual standards for good test administration--e.g., lighting, clear desk, quiet, etc.--should be met.

3. The actual working time which must be allotted to this test is 50 minutes.

4. Each student will need a test booklet, a separate answer sheet, scratch paper, two special electrographic pencils, and an eraser.

SPECIFIC DIRECTIONS FOR ADMINISTERING

1. Begin the test period by saying:

   "You will now be given your materials for a test on wave motion and sound."

2. Give each student an answer sheet and say:

   "Now fill in your name, your date of birth (year, month, and day), the science course you are presently taking (Sc. 10 or Sc. 20), and your science block (A, B, C, D, E, F, G)."

3. Allow sufficient time for this information to be recorded and then say:

   "I am now going to distribute the test booklets. Do not open them. Do not mark these booklets in any way." (Pass out the test booklets.) Then say: "Now study the directions on the cover page of the test booklet."

4. While the students are reading the directions, move about the room in order to make sure that everyone knows how to handle the answer sheet. When this has been done, say:

   "Are there any questions about how you are to take the test? No questions will be answered after the test has started." (Allow time for questions.)

5. Now say:

"You will have 50 minutes in which to complete this test. When you have finished checking your answers, close your booklet and leave it on your desk until you are given further instructions. Now open your test booklet and fold it so that only page 1 is showing. Start work now.

6. During the testing period move quietly about the room, making sure that the students are marking the answer sheets properly. At the end of 50 minutes say:

"Stop! Close your booklets."

7. Collect the materials and count them to make sure that all are returned.

Experimental | Form A

ACHIEVEMENT TEST
ON
WAVE MOTION AND SOUND

DIRECTIONS:

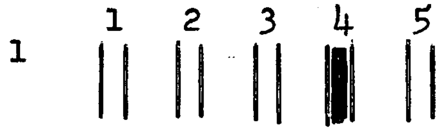
Do not open this booklet until you are told to do so.

This is a test of your knowledge of wave-motion and sound. For each question there are five possible answers. You are to decide which is the best one. You may answer a question even when you are not perfectly sure that your answer is correct, but you should avoid wild guessing. Do not spend too much time on any one question. You are not expected to be able to answer all the questions.

Study the sample question below, and notice how the answers are marked on the separate answer sheet.

Sample 1. The correct name for fluffy summer clouds is
1. cirrus
2. stratus
3. nimbus
4. cumulus
5. thunder

For Sample 1 the correct answer, of course, is "cumulus," which is answer 4. Now look at your answer sheet. It has five answer spaces as shown below. The answer is indicated



by making a heavy mark in the space (the pair of dotted lines) marked 4. Always make sure that the question number in the test booklet is the same as the question number on the answer sheet. Erase completely any answer you wish to change, and be careful not to make stray marks of any kind on your answer sheet or on your test booklet. When you finish a page, go on to the next page. Work as rapidly and as accurately as you can.

When you are told to do so, open your booklet and begin. The working time for this test is 50 minutes.

Go on to next page.

1. A <u>pulse</u> is a disturbance of
   1. low frequency
   2. small amplitude
   3. short wave length
   4. short duration
   5. low speed

2. The difference between wave motion and the motion of particles of matter is that
   1. waves travel at a steady speed.
   2. waves travel through anything.
   3. waves do not transfer the material in which they are travelling.
   4. waves travel faster.
   5. waves travel slower.

3. Which method of attracting someone's attention involves chiefly wave motion:
   1. throwing a stone
   2. letting perfume escape from a bottle
   3. creating a draft of air
   4. coughing
   5. throwing water

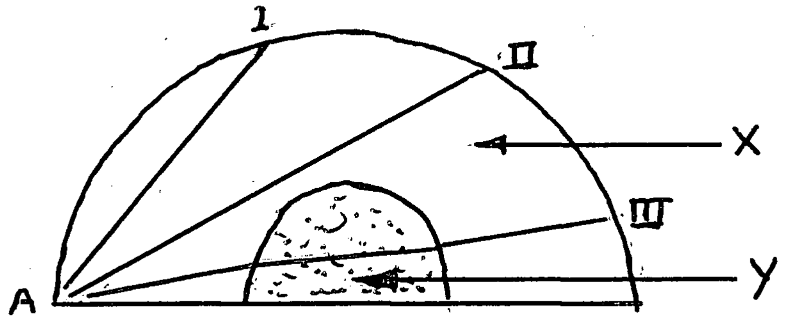
4. The word <u>medium</u> as used in describing wave motion refers to
   1. waves of average height.
   2. the material transmitting the wave.
   3. waves of average length.
   4. waves of average speed.
   5. the source producing the waves.

5. A shake-wave travelling along an iron bar makes the particles of matter in the bar
   1. move perpendicular to the direction of motion.
   2. move back and forth in the direction of motion.
   3. transfer with the wave.
   4. move in all directions.
   5. change in composition.

Questions 6 - 7 relate to the following information and diagram:

The diagram shows a cross-section of the inside of the earth. An earthquake occurred at A and the shock waves were assumed to have reached stations I, II and III in the manner shown below. Region X is considered to be a solid material with elastic properties while Region Y is probably a liquid.

Go to next page.



6. The waves received by stations I and II were probably
   1. Push-pull waves.
   2. shake waves.
   3. push-pull and shake waves.
   4. unknown since the kind of wave cannot be determined by the medium through which it travels.
   5. unknown because no familiar waves can travel at these depths in the earth.

7. The waves received by station III were probably
   1. shake waves.
   2. push-pull and shake waves.
   3. unknown because no familiar wave can travel through the core of the earth.
   4. push-pull waves.
   5. unknown since the kind of wave cannot be determined by the medium through which itn travels.

8. Beyond the earth, outer space will not transmit
   1. sound waves.
   2. light waves.
   3. radar waves.
   4. T.V. waves.
   5. radio waves.

Questions 9 - 10 relate to the following information and diagram:

The diagram below represents a rubber tube, of the same material throughout, stretched between two rigid walls. Two shake-pulses, A and B, of different heights, were generated at the same time at opposite ends (1 and 2) of the tube.

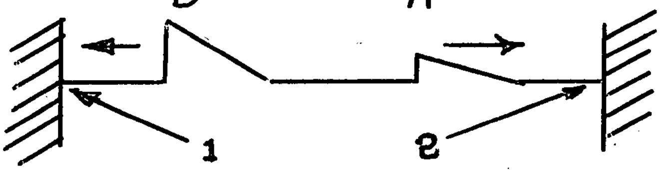
Go on to next page.

9. The best statement about the speeds of the pulses is that
   1. pulse A travels the faster.
   2. pulse B travels the faster.
   3. they travel at the same speed.
   4. the data is insufficient to compare the speeds.
   5. there is no relationship between the speeds.

10. The best statement about the speeds of shake-pulses and push-pull pulses is that
    1. shake-pulses are faster.
    2. push-pull pulses are faster.
    3. they travel at the same speed.
    4. the data is insufficient to compare the speeds.
    5. there is no relationship between the speeds.

Question 11 relates to the following information and diagram:

The diagram shows two shake-pulses travelling along a rope. The pulses were generated at the same time. Pulse A was generated at 1 and B at 2. The pulses were originally of the same height and shape. The ends of the rope are fastened to rigid walls.



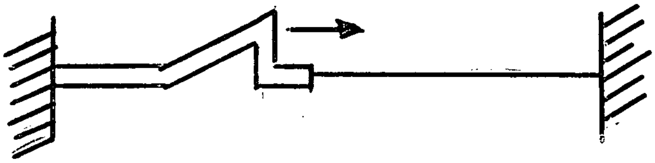
11. What shape and position will pulse B have after reflecting from the wall at 1?

    1. 
    2. 
    3. 
    4. 
    5. The data is insufficient for predicting how they will reflect.

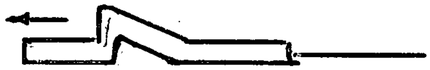
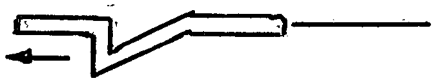
Questions 12 - 14 relate to the following information and diagram:

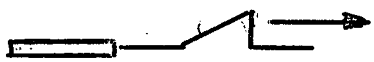
Go on to next page.

The diagram shows a heavy rope and a light rope joined together. A pulse is travelling on the heavy rope towards the boundary of the two ropes.



12. At the boundary the pulse will be
    1. entirely reflected.
    2. partially reflected.
    3. entirely transmitted.
    4. partially transmitted.
    5. partially reflected and partially transmitted.

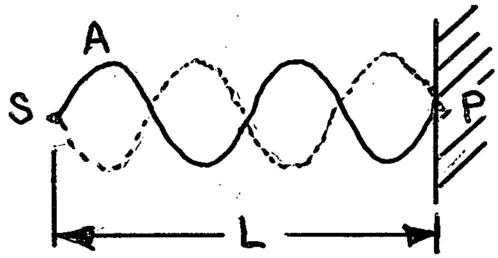
13. If the pulse reflects from the boundary, what shape and position would the reflected pulse have?
    1. This cannot be predicted because it does not reflect.
    2. 
    3. 
    4. 
    5. 

14. If the pulse is transmitted at the boundary, what shape and position will the transmitted pulse have?
    1. This cannot be predicted because it is not transmitted.
    2. 
    3. 
    4. 
    5. 

Questions 15-19 relate to the following information and diagram:

The diagram shows standing waves generated on a rope. The source of the waves is at S. The length of the rope is L.

Go on to next page.



15. Standing waves are produced by generating
    1. waves at both ends of the rope.
    2. a train of similar waves in step with the reflections.
    3. a series of pulses in step with the reflections.
    4. A slow succession of waves.
    5. a quick succession of waves.

16. The number of nodes <u>between</u> the ends of the rope, S and P, is
    1. eight.
    2. three.
    3. five
    4. four.
    5. none, there are no nodes.

17. The number of antinodes on the standing wave is
    1. five.
    2. three.
    3. four
    4. eight.
    5. none, there are no antinodes.

18. The wave length of the standing wave is
    1. L/2
    2. L/4
    3. L/5
    4. L/3
    5. L

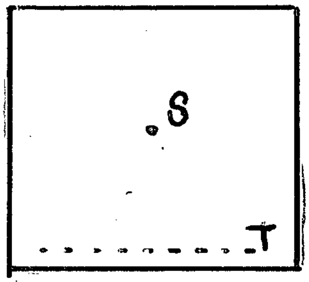
19. Which parts of a standing wave are stationary?
    1. nodes
    2. antinodes
    3. every part of the wave
    4. no part of the wave
    5. only the parts at the end of the rope

20. The frequency of a wave is given by the number of
    1. seconds per vibration.
    2. vibrations per second.
    3. meters travelled per unit time.
    4. pulses per unit distance.
    5. seconds to travel one unit distancé.

Go on to next page.

Questions 21-22 relate to the following diagram and information:

The diagram shows a ripple tank filled to the same depth with water. S is a point-source generating pulses and T is a wave generator consisting of many points closely spaced along a straight line.

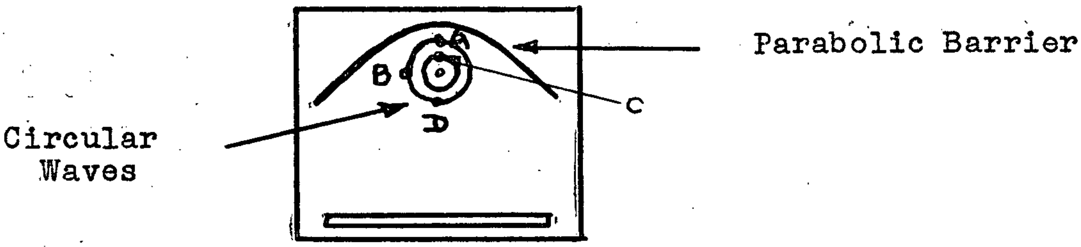


21. The pulse generated by S will be
    1. oval shaped.
    2. straight.
    3. parabolic.
    4. circular.
    5. of no particular shape.

22. The wave pulse generated by T will appear
    1. oval shaped.
    2. indefinite.
    3. circular.
    4. parabolic.
    5. straight.

Questions 23-25 relate to the following situation:

Circular waves are being generated at the focus of a parabolic reflecting surface in a uniformly filled ripple tank.



23. Which parts of the circular waves are travelling the fastest?
    1. point A
    2. point B
    3. point C
    4. point D
    5. They are travelling at the same speed.

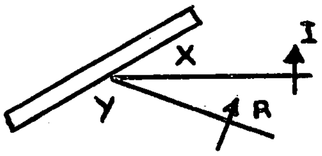
Go on to next page.

24. The shape of the waves after reflecting from the parabolic surface will be
    1. circular
    2. oval
    3. straight
    4. parabolic
    5. none of these

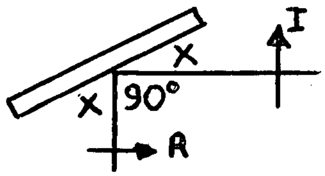
25. The straight wave generator is now used to produce straight waves. The shape of these waves after reflection from the parabolic surface will be
    1. straight
    2. spread out
    3. brought to a focus
    4. parabolic
    5. indefinite

26. The diagrams show a straight pulse I striking a straight reflecting surface set at an angle X (less than 45°) to the pulse, and the part of the pulse R that was reflected. Which diagram is correct?

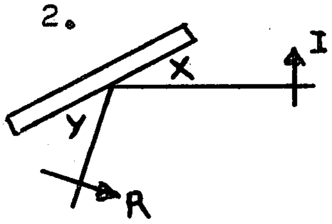
1.



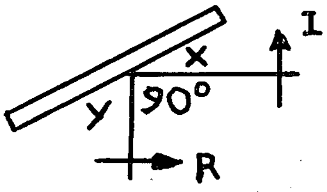
3.



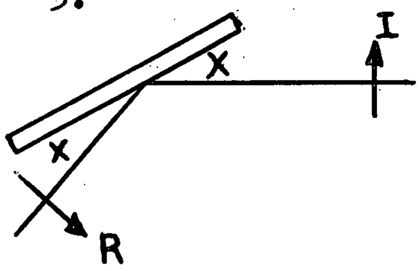
2.



4.



5.



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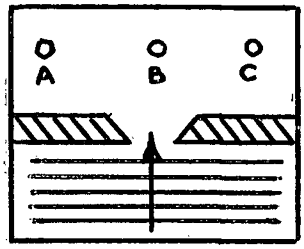
Questions 27-30 relate to the following situation:

A train of similar straight waves have been generated in a ripple tank filled with water to a uniform depth. The waves are directly approaching a barrier with an opening in it. The sides of the tank are lined to prevent reflections.



27. If the opening shown is much larger than the length of the waves, the waves on the other side of the opening will
    1. be nearly circular.
    2. pick up speed.
    3. be nearly straight.
    4. slow down.
    5. become shorter.

28. If the opening shown is made much smaller than a wave length, the waves on the other side of the opening will
    1. be nearly circular.
    2. be nearly straight.
    3. pick up speed.
    4. slow down.
    5. become shorter.

29. If the opening is the same as shown but the length of the waves is very small in comparison, and corks A, B, and C are placed as shown, which cork or corks will be disturbed most by the waves?
    1. C
    2. B and C
    3. A
    4. A and C
    5. A and B

30. Assume that the barrier is removed. An object is now placed in front of cork A where the opening in the barrier was before. The side of the object that is in the way of the waves is much shorter than the length of the waves. Which cork, or corks, will be disturbed most?
    1. A
    2. A and B
    3. B and C
    4. A and C
    5. They will be disturbed about the same.

Go on to next page.

31. Sound waves that differ only in amplitude differ in
    1. pitch
    2. wave length
    3. loudness
    4. quality
    5. speed

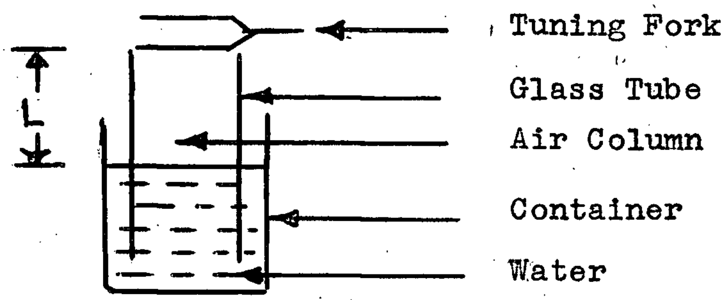
32. The pitch of a sound refers to the
    1. amplitude of the waves.
    2. quality of the waves.
    3. speed of the waves.
    4. frequency of the waves.
    5. length of the waves.

33. The speed of sound waves at room temperature ($20^{o}C$) is closest to
    1. 300 m/sec.
    2. 600 m/sec.
    3. 344 m/sec.
    4. 320 m/sec.
    5. 644 m/sec.

34. Communication by sound waves on the moon will probably be impossible because the
    1. sound would be quickly absorbed.
    2. moon has no atmosphere.
    3. sound would be quickly diffused.
    4. sound would reflect too much.
    5. sound would diffract too much.

Questions 35-36 relate to the following situation:

The diagram shows an air column that can be adjusted for length, and a vibrating tuning fork for setting the column of air into vibration. The length of the air column is L, and the frequency of the tuning fork is f. The length of the air column is adjusted to various positions at which resonance occurs.



35. The wave length of the sound waves in the shortest air-column at which resonance occurs is
    1. 4L
    2. 3L
    3. 2L
    4. L
    5. L/2

Go on to next page.

36. The wave length of the sound waves in the next shortest air-column at which resonance occurs is
    1. L/3
    2. 4L/3
    3. 2L/3
    4. L
    5. 5L/3

37. The frequencies of the notes in a diatonic scale are related to the key note C by
    1. whole number multiples.
    2. complex fractions.
    3. simple fractions.
    4. the square root of their frequencies.
    5. the square of their frequencies.

38. If two notes, an octave apart, are played on the same string of a cello, the two different lengths of string producing the notes are in the ratio of
    1. 8:1
    2. 16:1
    3. 4:1
    4. 1:1
    5. 2:1

39. What harmonic is a vibrating string sounding if it has one node in the middle?
    1. fourth harmonic
    2. second harmonic
    3. third harmonic
    4. first harmonic or fundamental
    5. none of these

40. A note played on a flute has a different quality than the same note played on a trumpet because the sounds produced differ in
    1. harmonic structure.
    2. loudness.
    3. pitch.
    4. transmission distance.
    5. speed of transmission.

<u>CHECK YOUR WORK CAREFULLY</u>

APPENDIX C

CLASSIFICATION OF SUBJECTS

AND

SCORES

TABLE XX

SUMMARY OF BASIC DATA* FOR GRADE NINES INCLUDING THE DISTRIBUTION OF STUDENTS IN THE VARIOUS EXPERIMENTAL GROUPS

Scholastic Aptitude Groups	Demonstration-Experiment Method						Pupil-Experiment Method					
	ST	IQ	RGS	U_1	U_2	U_3	ST	IQ	RGS	U_1	U_2	U_3
	1	121	45	13	28	30	1	124	60	10	26	24
	2	125	62	16	29	26	2	124	61	18	25	22
	3	123	63	13	27	24	3	129	46	7	16	18
	4	119	51	15	32	32	4	121	61	10	18	16
<u>High Third</u>	5	127	55	13	29	28	5	120	59	12	26	24
	6	132	66	13	34	29	6	125	65	9	29	26
(IQ: 119-155)	7	119	50	8	33	35	7	145	60	15	30	26
	8	120	41	11	23	27	8	128	59	10	16	14
	9	127	57	17	32	30	9	119	55	16	20	19
	10	155	61	11	27	23	10	121	62	12	34	31
	1	113	52	8	24	26	1	114	52	14	23	24
	2	113	56	14	20	19	2	113	45	8	16	20
	3	113	40	10	20	25	3	115	36	13	21	26
	4	117	52	9	22	23	4	114	44	8	28	32
<u>Middle Third</u>	5	116	47	10	27	30	5	116	53	11	17	18
	6	116	51	7	28	30	6	116	64	19	32	28
(IQ:113-118)	7	118	54	11	23	23	7	115	36	11	19	25
	8	117	57	9	30	30	8	118	49	11	18	20
	9	113	34	7	23	30	9	117	58	12	28	27
	10	114	46	9	28	31	10	115	56	11	13	13
	1	110	39	5	25	31	1	104	58	9	28	28
	2	92	51	12	20	23	2	92	61	8	22	22
	3	111	41	12	20	24	3	98	45	13	24	28
	4	105	52	14	28	29	4	112	56	18	29	28
<u>Low Third</u>	5	101	48	15	25	27	5	111	47	11	13	16
	6	110	49	4	17	20	6	109	44	9	20	24
(IQ: 92-112)	7	98	45	5	31	36	7	104	45	7	10	14
	8	112	47	8	25	28	8	110	56	11	17	17
	9	99	44	12	19	23	9	94	44	6	15	21
	10	101	43	7	26	31	10	103	55	3	23	25

*ST refers to the student number.
IQ refers to the Henmon-Nelson IQ score.
RGS refers to the Read General Science Pre-Test raw score.
U_1 refers to the Unit pre-test raw score.
U_2 refers to the Unit post-test raw score.
U_3 refers to the adjusted Unit post-test score.

TABLE XXI

SUMMARY OF BASIC DATA* FOR GRADE TENS
INCLUDING THE DISTRIBUTION OF STUDENTS
IN THE VARIOUS EXPERIMENTAL GROUPS

Scholastic Aptitude Groups	Demonstration-Experiment Method						Pupil-Experiment Method					
	ST	IQ	RGS	U_1	U_2	U_3	ST	IQ	RGS	U_1	U_2	U_3
	1	146	66	11	37	32	1	142	64	18	31	25
	2	140	65	16	35	30	2	141	66	18	36	30
	3	140	60	9	38	35	3	133	60	17	34	30
	4	138	64	12	32	28	4	132	69	20	31	24
High Third	5	135	53	11	34	33	5	130	66	22	32	26
	6	133	56	11	28	27	6	130	51	11	26	26
(IQ:128-146)	7	132	59	11	28	26	7	129	61	13	25	22
	8	130	58	11	35	33	8	129	49	10	21	22
	9	128	56	11	27	26	9	128	61	16	30	27
	10	128	46	8	24	26	10	128	59	10	33	31
	1	127	58	13	26	24	1	127	65	21	27	22
	2	125	54	16	33	32	2	126	50	6	20	22
	3	124	55	6	24	24	3	125	62	17	18	14
	4	124	59	13	31	31	4	123	64	11	28	25
Middle Third	5	124	46	4	34	34	5	123	65	11	24	21
	6	124	53	12	24	24	6	122	46	11	26	28
(IQ:121-127)	7	123	62	17	28	28	7	122	56	12	28	27
	8	123	60	11	27	27	8	121	61	12	26	23
	9	123	52	8	30	30	9	121	60	8	20	19
	10	122	52	11	29	29	10	121	67	12	23	19
	1	120	54	9	28	28	1	120	51	9	26	27
	2	119	55	15	29	28	2	120	65	22	32	27
	3	117	44	12	20	23	3	119	63	15	25	22
	4	115	59	10	36	35	4	118	51	11	28	29
Low Third	5	114	59	15	30	28	5	117	66	14	28	24
	6	111	47	10	19	22	6	117	56	8	23	24
(IQ:104-120)	7	109	47	8	20	23	7	115	58	13	29	28
	8	109	42	6	21	26	8	108	59	7	26	26
	9	105	55	9	28	29	9	117	44	8	19	23
	10	104	39	9	10	16	10	104	50	9	20	23

* ST refers to the student number.
IQ refers to the Henmon-Nelson IQ score.
RGS refers to the Read General Science pre-test raw score.
U_1 refers to the Unit pre-test raw score.
U_2 refers to the Unit post-test raw score.
U_3 refers to the adjusted Unit post-test score.

APPENDIX D

COMPUTATION OF THE UNIT TEST RELIABILITY

RELIABILITY OF UNIT POST-TEST

Hoyt's formula for the reliability is

$$r_{tt} = \frac{n}{n-1} \cdot \frac{KS_s + S_i - T(T + K)}{KS_s - T^2},$$

where:

r_{tt} is the coefficient of reliability,
N is the number of items,
K is the number of subjects,
S_s is the sum of squares of the scores for all subjects,
S_i is the sum of squares of the number of correct responses for each item,
T is the sum of the scores for all subjects.

The data related to the computation are as follows:

n	K	T	T^2	S_s	S_i
40	119	3,044	9,265,936	81,958	248,502

Using this formula, $r_{tt} = .79$. The standard error, computed from the formula:

$$SD_E = SD \sqrt{1-r_{tt}}$$

is 2.71.

APPENDIX E

TESTS OF NORMALITY

TABLE XXII

FREQUENCY AND CUMULATIVE PERCENTAGES FOR HENMON-NELSON PRE-TEST SCORES FOR GRADES NINE AND TEN

Score	Frequency	Cumulative Per Cent	Frequency	Cumulative Per Cent
	Grade 9		Grade 10	
153-155	1	100.0		
150-152				
147-149				
144-146	1	98.3	1	100.0
141-143			2	98.3
138-140			3	95.0
135-137			1	90.0
132-134	1	96.7	4	88.3
129-131	1	95.0	5	81.7
126-128	2	93.3	7	73.3
123-125	5	90.0	11	61.7
120-122	5	81.7	9	43.3
117-119	8	73.3	7	28.3
114-116	10	60.0	3	16.7
111-113	9	43.3	1	11.7
108-110	4	28.3	3	10.0
105-107	1	21.7	1	5.0
102-104	3	20.0	2	3.3
99-101	3	15.0		
96-98	2	10.0		
93-95	1	6.7		
90-92	3	5.0		

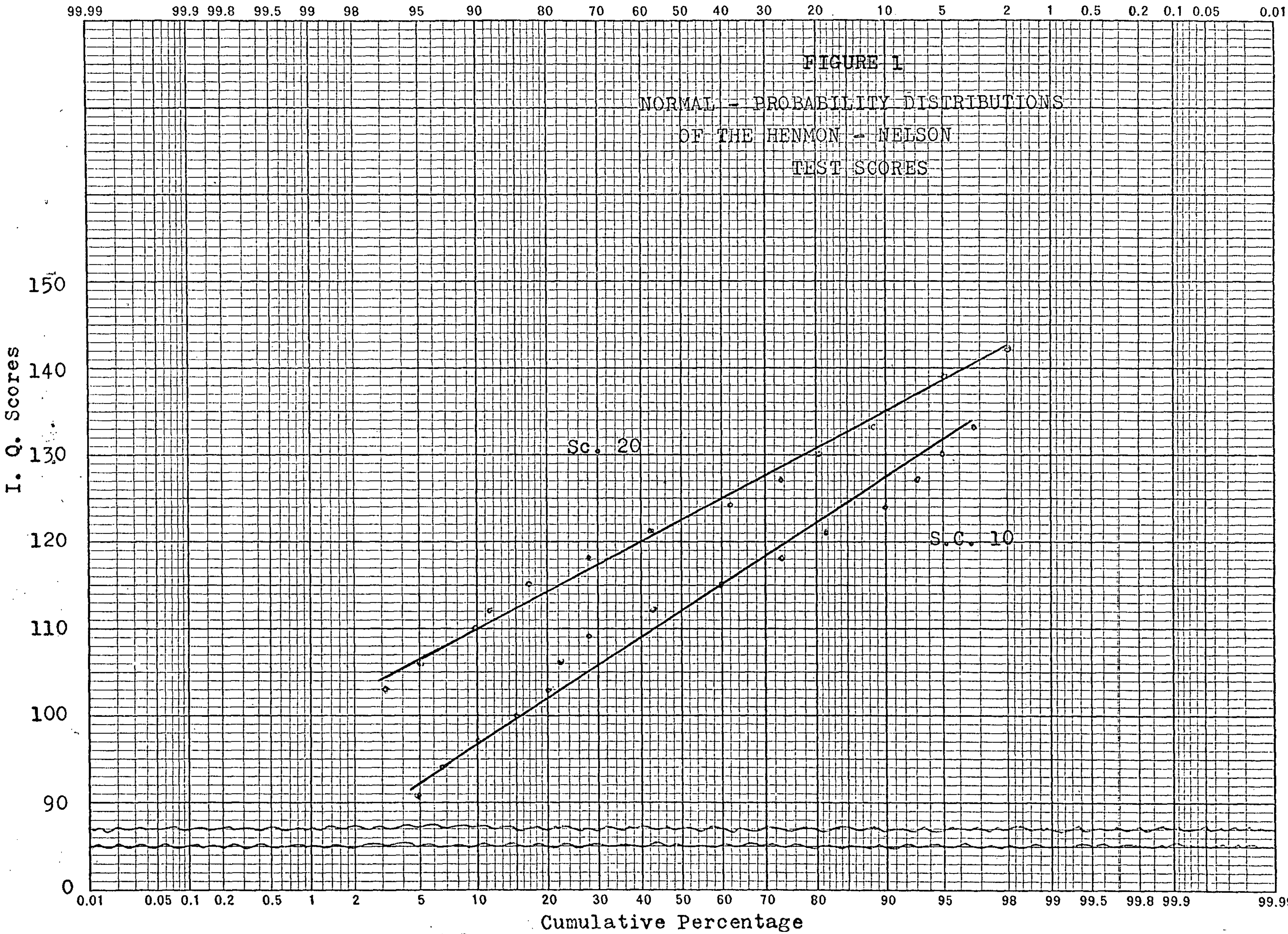


FIGURE 1
NORMAL - PROBABILITY DISTRIBUTIONS
OF THE HENMON - NELSON
TEST SCORES
Sc. 20
S.C. 10
I. Q. Scores
150
140
130
120
110
100
90
0
99.99 99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99
Cumulative Percentage

TABLE XXIII

FREQUENCY AND CUMULATIVE PERCENTAGES FOR THE READ GENERAL SCIENCE PRE-TEST SCORES FOR GRADES NINE AND TEN

Score	Frequency	Cumulative Per Cent	Frequency	Cumulative Per Cent
	Grade 9		Grade 10	
67-69			2	100.0
64-66	3	100.0	11	96.7
61-63	7	95.0	6	78.3
58-60	6	83.3	13	68.3
55-57	8	73.3	7	46.7
52-54	6	60.0	6	35.0
49-51	7	50.0	6	25.0
46-48	5	38.3	5	15.0
43-45	11	30.0	2	6.7
40-42	3	11.7	1	3.3
37-39	1	6.7	1	1.7
34-36	3	5.0		

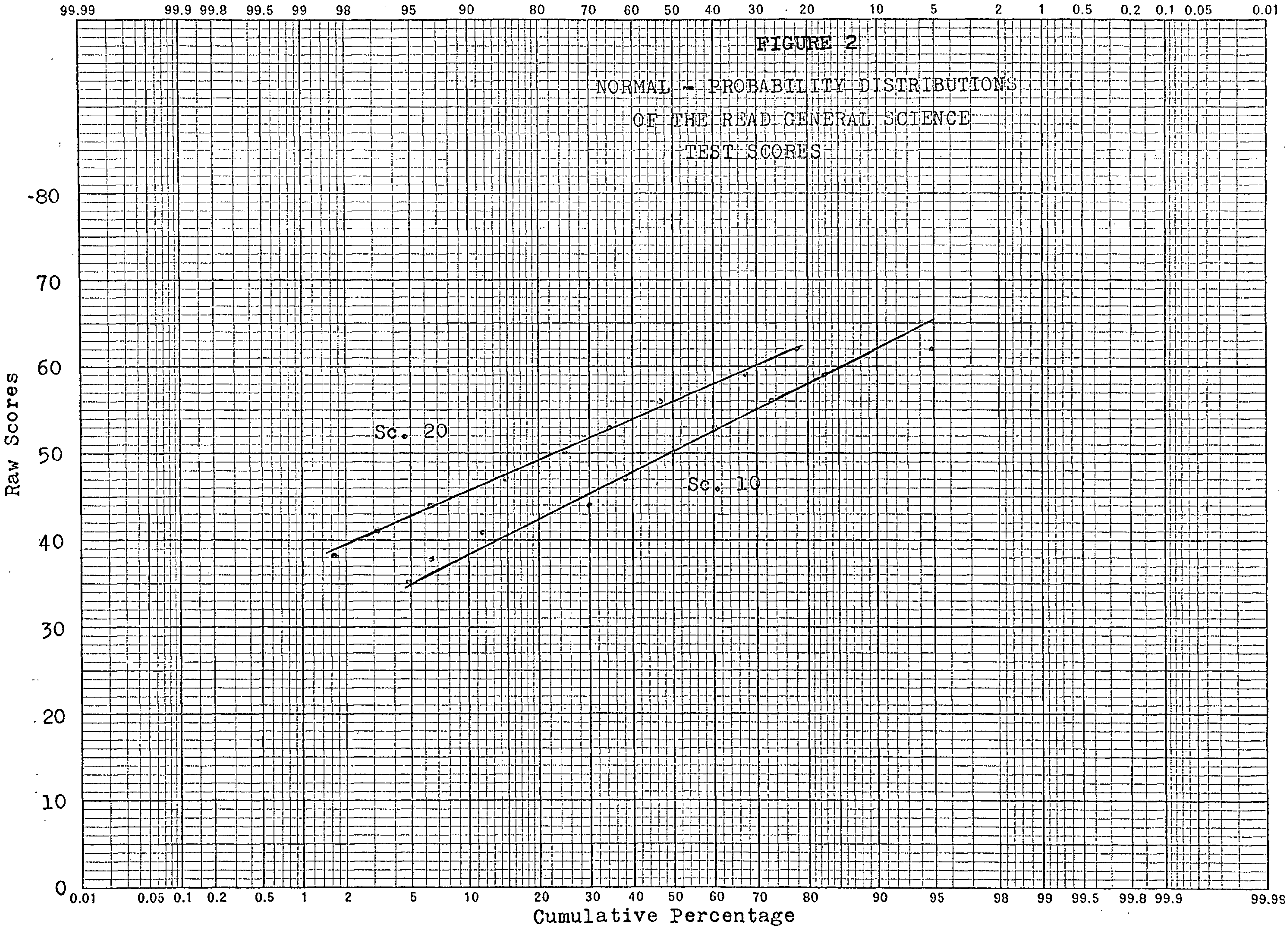


FIGURE 2

NORMAL - PROBABILITY DISTRIBUTIONS OF THE READ GENERAL SCIENCE TEST SCORES

TABLE XXIV

FREQUENCY AND CUMULATIVE PERCENTAGES FOR THE UNIT POST-TEST SCORES IN GRADES NINE AND TEN

Score	Frequency	Cumulative Per Cent	Frequency	Cumulative Per Cent
	Grade 9		Grade 10	
38-40			1	100.0
35-37			5	98.3
32-34	6	100.0	8	90.0
29-31	6	89.8	10	76.7
26-28	13	79.7	17	60.0
23-25	10	57.6	8	31.7
20-22	10	40.7	7	18.3
17-19	7	23.7	3	6.7
14-16	4	11.7		
11-13	2	5.1		
8-10	1	1.7	1	1.7

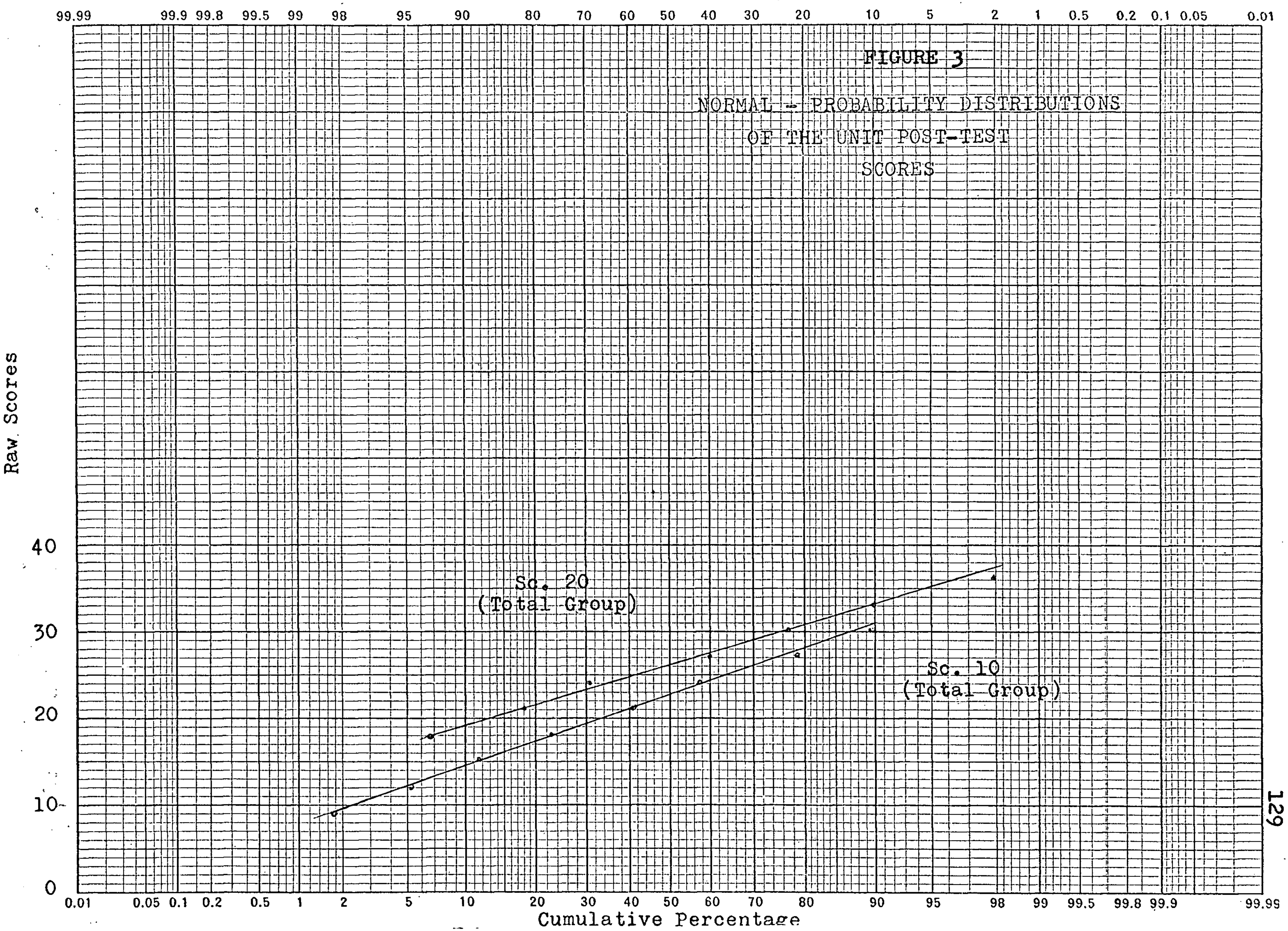


FIGURE 3

NORMAL - PROBABILITY DISTRIBUTIONS OF THE UNIT POST-TEST SCORES

TABLE XXV

FREQUENCY AND CUMULATIVE PERCENTAGES FOR THE UNIT POST-TEST SCORES IN THE UPPER AND MIDDLE SCHOLASTIC APTITUDES GROUPS FOR GRADES NINE AND TEN

Scores	Frequency	Cumulative Per Cent	Frequency	Cumulative Per Cent
	Upper 9		Upper 10	
38-40			1	100.0
35-37			4	95.0
32-34	5	100.0	5	75.0
29-31	3	73.4	3	50.0
26-28	5	57.9	4	35.0
23-25	2	31.6	2	15.0
20-22	1	21.1	1	5.0
17-19	1	15.8		
14-16	2	10.5		
	Middle 9		Middle 10	
32-34		100.0	2	100.0
29-31		95.0	4	89.5
26-28		90.0	7	68.4
23-25		65.0	3	31.6
20-22		45.0	2	15.8
17-19		25.0	1	5.3
14-16		10.0		
11-13		5.0		

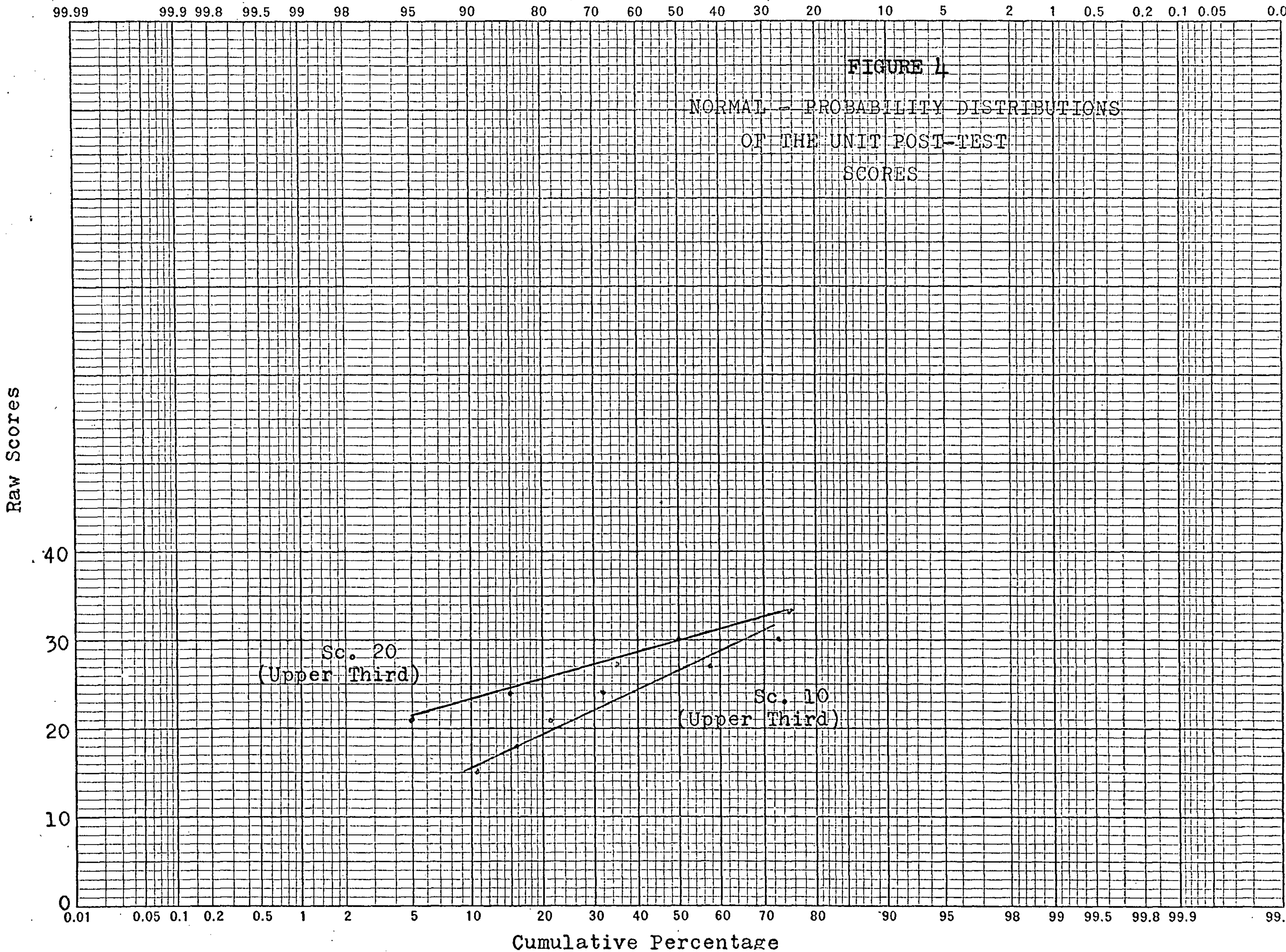


FIGURE 4

NORMAL - PROBABILITY DISTRIBUTIONS
OF THE UNIT POST-TEST
SCORES

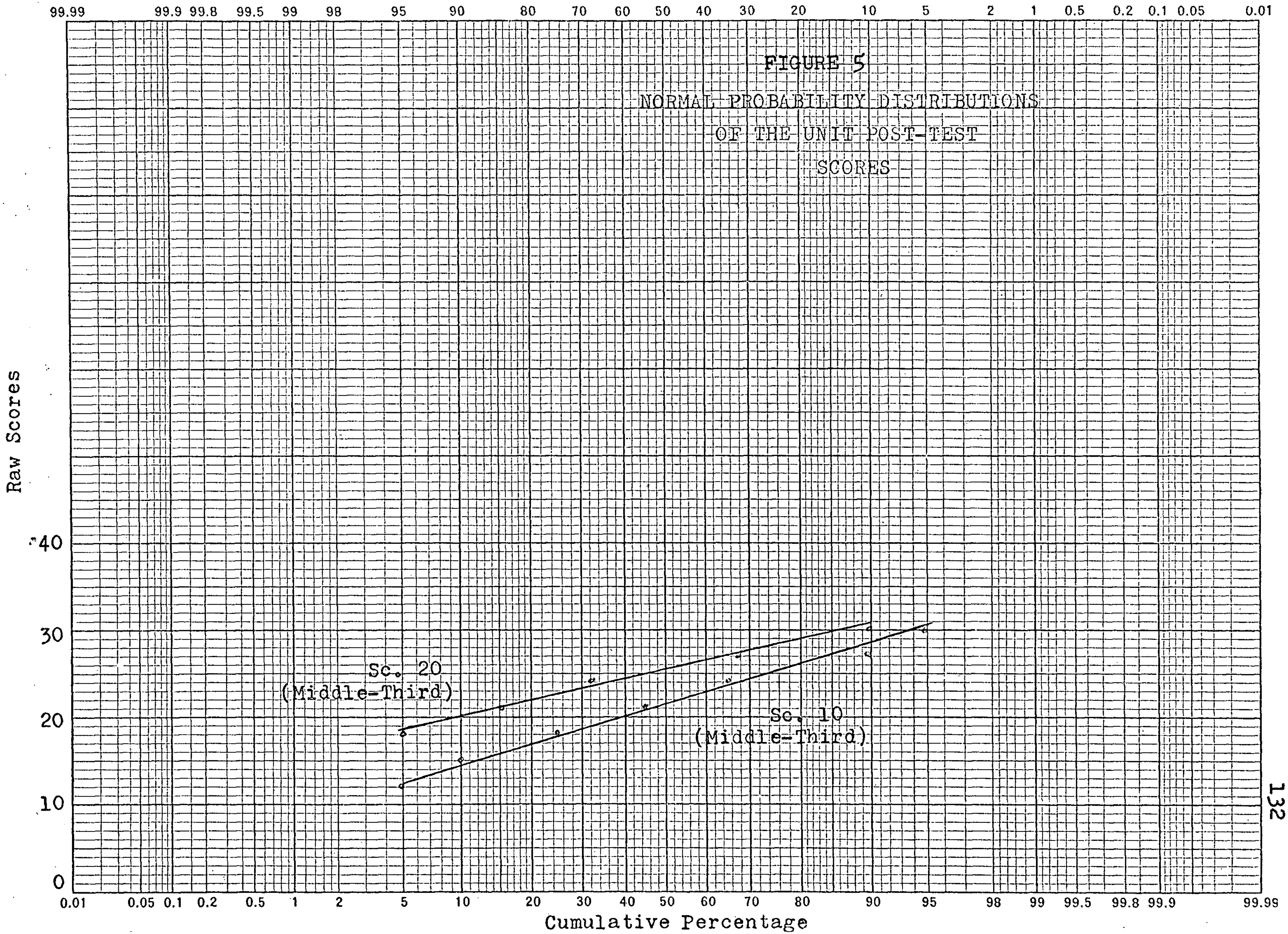


FIGURE 5

NORMAL PROBABILITY DISTRIBUTIONS
OF THE UNIT POST-TEST
SCORES

TABLE XXVI

FREQUENCY AND CUMULATIVE PERCENTAGES FOR THE UNIT POST-TEST SCORES IN THE LOWER SCHOLASTIC APTITUDE GROUPS OF GRADE NINE AND TEN AND IN THE TWO METHODS GROUPS

Scores	Frequency	Cumulative Per Cent	Frequency	Cumulative Per Cent
	Lower 9		Lower 10	
35-37			1	100.0
32-34			1	95.2
29-31	2	100.0	3	90.8
26-28	3	90.0	6	76.2
23-25	5	75.0	3	47.6
20-22	4	50.0	4	33.3
17-19	3	30.0	2	14.3
14-16	1	15.0		
11-13	1	10.0		
8-10	1	5.0	1	4.8
	Demonstration-Experiment		Pupil-Experiment	
38-40	1	100.0		
35-37	4	98.3	1	100.0
32-34	8	91.5	6	98.3
29-31	9	78.0	7	88.3
26-28	15	62.7	15	76.7
23-25	10	37.3	9	51.2
20-22	8	20.3	8	36.7
17-19	3	6.8	7	23.3
14-16			4	11.7
11-13			2	5.0
8-10	1	1.7	1	1.7

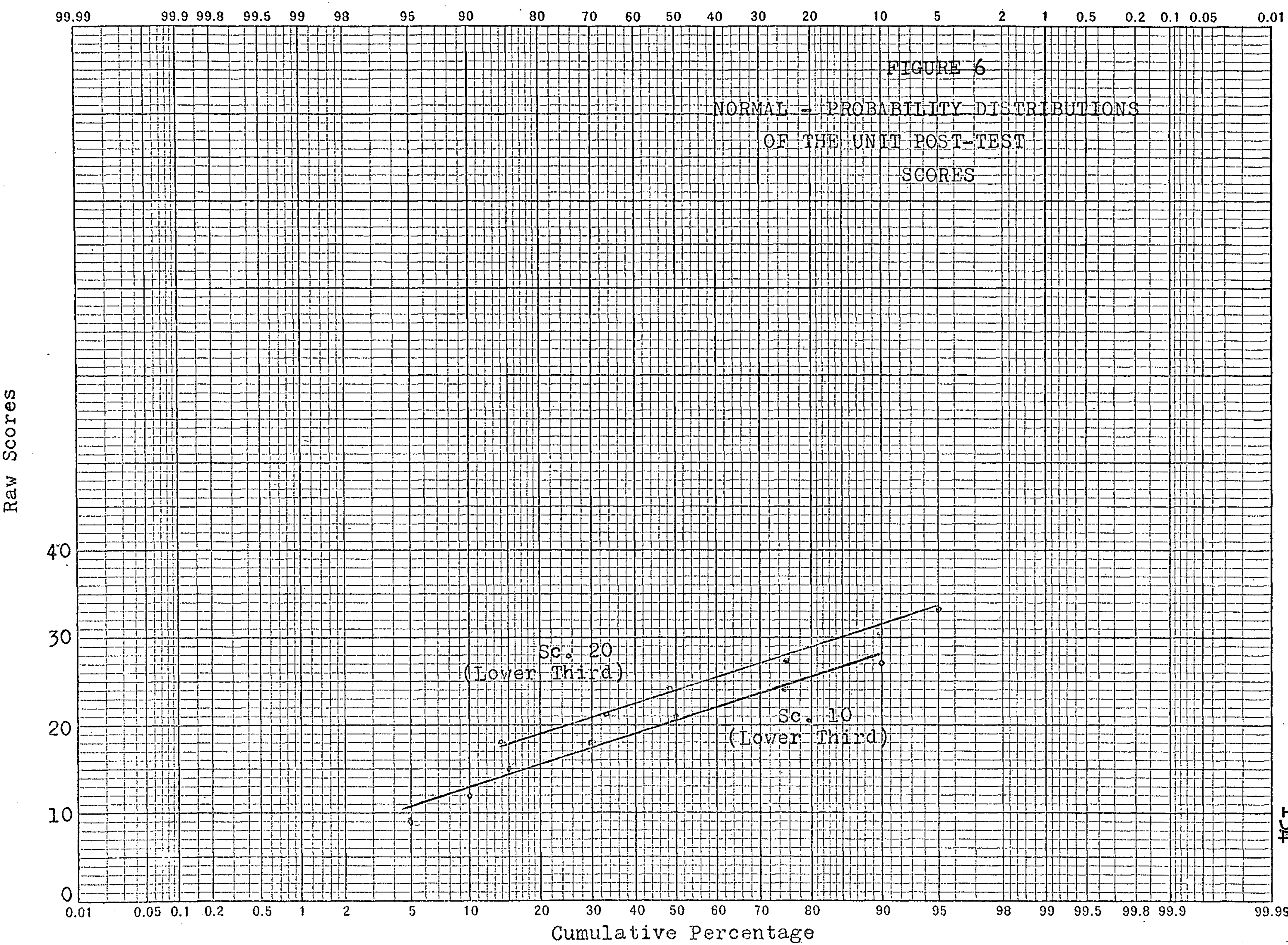


FIGURE 6

NORMAL - PROBABILITY DISTRIBUTIONS OF THE UNIT POST-TEST SCORES

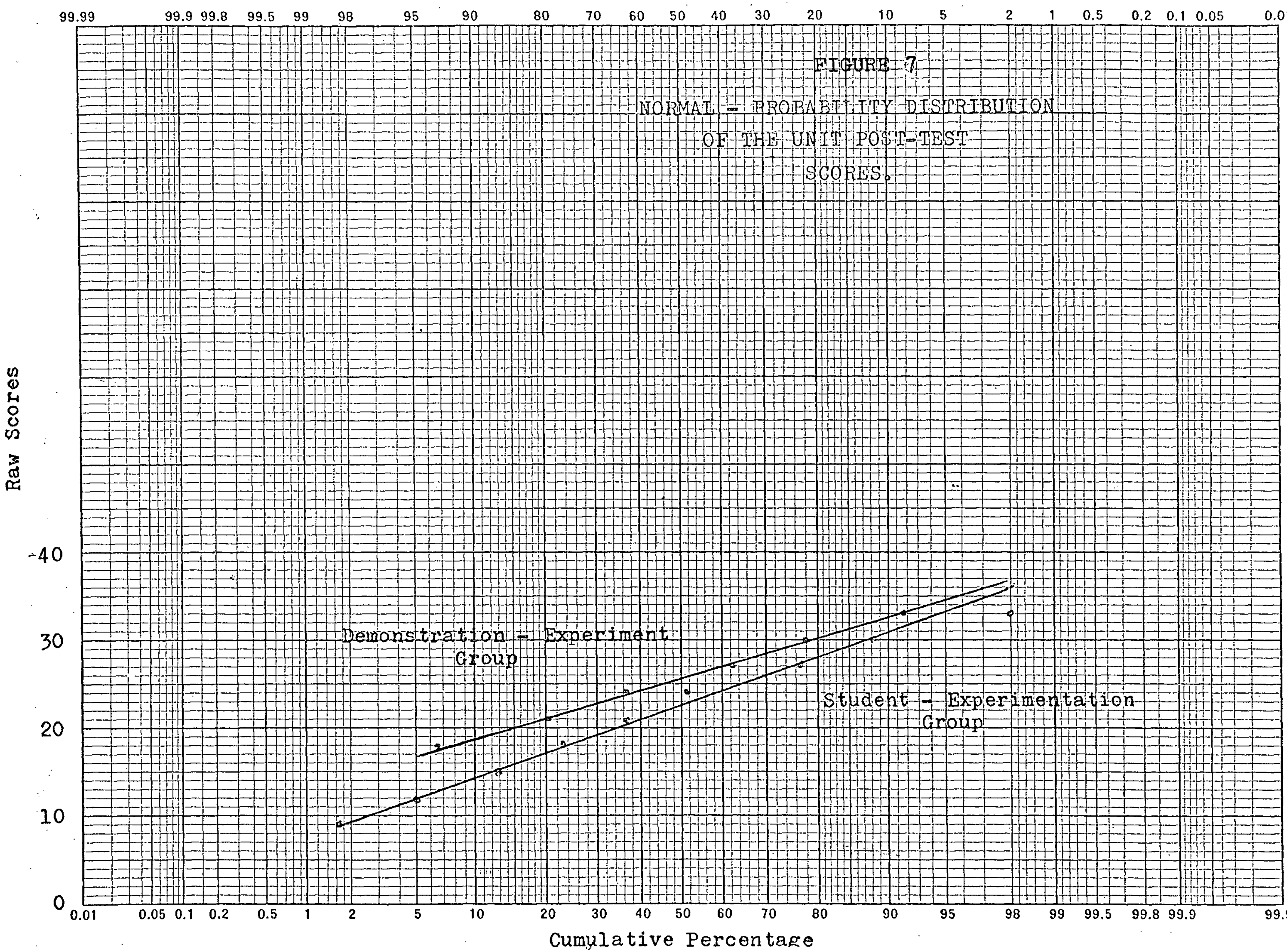


FIGURE 7
NORMAL - PROBABILITY DISTRIBUTION
OF THE UNIT POST-TEST
SCORES.
Raw Scores
0
10
20
30
40
Cumulative Percentage
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99
Demonstration - Experiment
Group
Student - Experimentation
Group