AN INVESTIGATION OF THE SUITABILITY OF THE PHYSICAL SCIENCE STUDY COMMITTEE PROGRAM FOR USE IN MANITOBA SCHOOLS

A Thesis

Presented to

the Faculty of Graduate Studies and Research

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Education

by

Richard Malcolm Mutchmor

August 1968

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ABSTRACT

I. THE PROBLEM

This study examined the suitability of the P.S.S.C. physics syllabus for use in the University Entrance Course of Manitoba high schools. The term suitability in this investigation was defined as the P.S.S.C. course being acceptable to the teachers who offer the instruction and of an appropriate level of difficulty for the students who study the course.

II. THE EXPERIMENTAL METHOD

To assess the acceptance of the P.S.S.C. syllabus by teachers, a teacher opinionnaire was developed. Thirty items for the opinionnaire were validated by submitting them to a panel of judges. These thirty statements were then circulated to all the teachers in Manitoba using the P.S.S.C. syllabus in the 1967-68 school year, who were asked to react to each statement by indicating their position on a five point scale. Eighty percent of the opinionnaires were returned and were scored using the Lickert method of summated ratings. From these data, the level of acceptance of the P.S.S.C. syllabus by Manitoba teachers was assessed.

The achievement of the 262 Grade XI and the 205 Grade XII students who formed the Manitoba pilot study groups and followed the P.S.S.C. syllabus in the 1963-64 and the 1964-65 school years was compared to the achievement of students

in the United States. Tests number 1, 3, 4, 5, 6 and 7 of the Tests of the Physical Science Study Committee, Series O, were administered to the Manitoba students. The mean score of the Manitoba students on each of the tests was determined and the 95% and 99% confidence intervals were found. The mean score of the United States sample furnished by the publisher of the tests was compared to these confidence intervals.

III. THE FINDINGS

The following conclusions were drawn from the investigation. First, since in five of the six tests given, the Manitoba students achieved at a level equivalent to or better than the students in the United States, it was concluded that the P.S.S.C. syllabus was of an appropriate level of difficulty. Secondly, the P.S.S.C. syllabus was highly acceptable to the teachers of Manitoba as measured by the teacher opinionnaire.

Based upon this evidence, it was further concluded that the P.S.S.C. course is suitable, as defined, for use in Manitoba high schools with the students in the University Entrance Course who choose physics as one of their options.

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CHAPTER I

INTRODUCTION

I. STATEMENT OF THE PROBLEM

The purpose of this investigation is to ascertain the suitability of the Physical Science Study Committee (P.S.S.C.) course of study for adoption as the high school physics course in the Manitoba schools University Entrance Course. Implied in the adoption the P.S.S.C. course is also the use of P.S.S.C. developed teaching aids and materials and the utilization of the teaching methods prescribed by the P.S.S.C. developed philosophy.

The term suitability is defined for this investigation as being acceptable to teachers and of an appropriate level of difficulty such that if used by the students in Manitoba electing a physics option in the high school University Entrance Course, their achievement would be equivalent to that of students in the United States for whom the course was designed.

In this investigation the opinion and reaction of Manitoba teachers who are currently using the P.S.S.C. text and materials will be assessed in evaluating the first aspect of the suitability of the course. The second aspect will be judged by assessing the achievement of Manitoba students in the P.S.S.C. course and the conclusion as to its suitability will be based upon whether or not their achievement is equivalent to that of students in the United States of America.

II. IMPORTANCE OF THE STUDY

In 1966 the curriculum revision committee for physics recommended the adoption of the P.S.S.C. course for Manitoba schools. Soon high school graduates, having studied P.S.S.C. as their physics option will be presenting themselves at the University in significant numbers. If the success of these students and those that follow them is to be insured, the need for a direct assessment of their ability to cope with the course seems obvious. The need for this evaluation is magnified by the rapidity with which alternative programs are becoming available. Since P.S.S.C. has appeared on the high school scene, others such as Harvard Project Physics, the Nuffield Project and Engineering Concepts Physics have been put forward in the United States and the United Kingdom. Should P.S.S.C. be deemed inadequate or inappropriate close examination of the alternative courses in Physics should begin without delay. The purchase of texts, films, specialized teaching aids and laboratory materials which would become obsolete if P.S.S.C. is abandoned is only one of the decrements. Probably of greater importance is the loss of manpower. Hundreds of physics teachers have taken or are currently taking special training specifically designed to prepare them for the efficient performance of their role as teacher of this course and indications are that teachers would have to take additional training should one of the alternatives be selected to replace P.S.S.C. In the light of these conditions then it would be inexcuseable to delay the evaluation of the P.S.S.C. course any longer.

III. INVESTIGATIONS AND SETTING

For the purpose of the investigation an experimental group of 262 students entering Grade XI in September 1963 was selected. These students were given the Grade XI course recommended by the curriculum committee (Appendix A) by four teachers each of whom has had experience teaching traditional physics and also have taken the special training recommended by the P.S.S.C. Those students from the Grade XI group who continued their study of physics composed the Grade XII group. These students were given the Grade XII course recommended by the curriculum committee by the same four teachers who offered the Grade XI course.

To evaluate teacher acceptance of the P.S.S.C. program and opinionnaire was developed using the techniques of the Lickert Method of Summated Ratings. This opinionnaire was sent to the eighty teachers in Manitoba who were using the P.S.S.C. in the 1967-68 school year. The opinionnaires were returned by 64 teachers and these were analyzed on the bases of items as well as total response.

IV. LIMITATIONS OF THE STUDY

This study is horizontal in design and therefore yields no information or evidence which permits comparison of the experimental group's achievement in university with that of some control group. It might be argued that to be suitable, the P.S.S.C. course should produce students who will achieve in university at a significantly higher level than a comparative group studying traditional materials.

Such a study if undertaken would undoubtedly produce useful information, but perhaps too would only reveal that the universities are at present better organized to receive students with a traditional background and hence would become a test of the universities rather than a test of P.S.S.C. Further consideration would have to be given to the possibility that the universities, if reoriented to accept P.S.S.C. students could capitalize on their background and might or might not be able to carry them farther in their study and understanding of the discipline.

No conventional testing device yet designed will serve as a single measure to be applied to both traditional and P.S.S.C. students.

> The course differs sharply from most secondary-school physics courses both in selection of content and in style of development. Comparison with other

> courses is not a matter of evaluating the relative merit of different methods of teaching toward the same objectives. Rather, such a comparison involves questions as to the choice of objectives themselves. Close scrutiny of the courses is enough to confirm this fundamental difference. Further confirmation comes from the few instances in which standard examinations have been given to P.S.S.C. students and P.S.S.C. examinations have been given to students in standard courses. The results show that the students have studied different courses....Certainly it is possible to design an examination on which matched groups of P.S.S.C. students and students from other physics courses would achieve equivalent score distributions. This procedure would hardly provide a comparison. It would prove only that such an examination can be prepared.[1]

To compare equivalent groups studying traditional and P.S.S.C. materials by examining their achievement on a standardized test would introduce a bias toward one group or the other. For example if the Cooperative Science Tests were used to evaluate the groups' achievement, it would favor the traditional students whereas if the Educational Testing Service P.S.S.C. tests were used, the P.S.S.C. students would be favored. For this reason this study has been confined to a comparison between Manitoba students and those of the United States, both groups having studied physics using the P.S.S.C. materials.

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[1]Gilbert C. Finlay, "The Physical Science Study Committee," Modern Viewpoints in the Curriculum (New York: McGraw-Hill Inc. 1964), p.46.

CHAPTER II

REVIEW OF LITERATURE

I. A BRIEF HISTORY OF THE DEVELOPMENT OF P.S.S.C.

The Physical Science Study Committee was formed in 1956 and, under the leadership of Professor Jerrold R. Zacharias of Massachusetts Institute of Technology, undertook a study of the teaching of physics in secondary schools.

> The Physical Science Study Committee, as its name implies, would have preferred to create a two-year course in physics and chemistry rather than the one-year course in physics that it finally produced. Yet, it was necessary to recognize that most American secondary schools as they are now constituted would not find it possible to fit a two-year course into their structures.[1]

Originally the committee planned to produce teaching aids such as films and laboratory apparatus but early investigations and discussions gave strong indication that a major revision of content and approach was needed.

> Studies by the American Institute of Physics, the American Association of Physics Teachers and the National Science Teachers Association supported the first conclusions of the Committee that (a) secondary school physics textbooks in general presented the subject from a point of view that dated back half a century and no longer reflected the views of the scientific community, (b) genuine attempts to add new material had resulted in a patchwork quality in which the unity of physics had disappeared, (c) the amount of material in textbooks had become so great

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[1]Jerrold R. Zacharias and Stephen White, New Curricula (New York: Harper and Row, 1964), p.70.

> that it could not be reasonably taught in an academic year, (d) much of the new material reflected the increasing importance of technology in our society, but resulted in further overloading of the source and further minimizing of the concepts of science itself.[2]

In considering tentative syllabi presented by various groups at their early meetings the Committee realized that a good deal of subject matter treated in the conventional courses would have to be omitted. Any material dealing with technology was dropped and some material with considerable significance and interest was also omitted.

> It was decided that the course would be directed toward familiarizing the student with two central notions of modern physics: the wave-particle duality and the modern concept of the atom. Behind this decision was the view that these two notions lay at the heart of the modern Physicist's outlook upon his universe, and that it was this outlook that the course should convey.[3]

O.L. Brauer[4] has presented a formidable list of topics not included in P.S.S.C. but which receives considerable prominence in conventional physics courses. Most items of the list presented represent technological devices, but there are some such as hydrostatics, heat and expansion, and sound, which are indeed purely physics.

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[2]Elbert P. Little, "The Physical Science Study Committee" Harvard Educational Review. 29: 1, 1959. p.1.

[3]Zacharias and White, op.cit., p.71.

[4]O. L. Brauer, "Something Dangerously New In Physics Teaching" Science Education, 47: 366, 1963.

To be retained, each item of subject matter had to meet the following criteria:

(1) To stress the major achievements of physics, such as the great conservation principles.
(2) To give insight into the way in which these powerful ideas were conceived, nurtured and sometimes overthrown by even more powerful ideas.
(3) To present a unified story in which the interconnections within physics were brought to light.
(4) To show physics as a human activity comparable in significance with the humanities, the languages and the other major studies of high school students.[5]

During the summer of 1957 a variety of projects were begun. A group of university physicists and high school physics teachers began work on a text book for the new course. Others worked on new forms of simple apparatus, teaching films, a teacher's guide and other aids. A special effort was made to have the materials ready for use in the fall of 1957. In the 1957-58 school year 8 teachers, all in the United States, used these materials with some 300 students. These teachers fed appraisals back to the committee who made revisions accordingly. In the summer of 1958, 270 high school physics teachers attended one of five summer institutes sponsored by the National Science Foundation at which the P.S.S.C. course was the subject of study. During the following school year these teachers used the P.S.S.C. materials with approximately 11,000

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[5]Little, <u>op.cit.</u>, p.2.

students. These numbers grew annually, and by 1962-63 in the United States, 3,000 teachers and 125,000 students were estimated to be using the P.S.S.C. materials.

Although P.S.S.C. is still enjoying a steady annual growth in the numbers of teachers and students involved in its use, there has been some dropout, which has currently been estimated to be considerably less than 5%. In 1961-62 however, there were 1,800 teachers, 225 dropped P.S.S.C. the following year for following reasons:

33 - alternate physics and chemistry, 59 are not teaching
39 - changed positions and could not use the course, or are teaching courses other than physics
23 - have scheduling problems or other miscellaneous difficulties which prevent their teaching P.S.S.C. this year
71 - gave no reason, or indicated the course was not suitable for their students[6]

II. A BRIEF HISTORY OF THE INTRODUCTION AND GROWTH OF P.S.S.C. IN MANITOBA

In September 1962, the P.S.S.C. program was introduced in Manitoba at Gordon Bell High School in Winnipeg. The group, which formed the basis for a pre-pilot study was composed of twenty-eight Grade XI students, 16 male and 12 female who had been selected because of their above average performance in science and mathematics. Each student had obtained an average of 70% or better in science and mathe-

[6]Quarterly Report (Educational Services Incorporated, Watertown, Mass. Summer-Fall, 1964), p.9.

matics in their Grade X year and had indicated a willingness to participate in the program. The class was taught by the writer who had taken the special P.S.S.C. teacher training at a National Science Foundation (N.S.F.) sponsored summer institute at Nebraska Wesleyan University.

All students wrote and were successful on a special examination for Grade XI standing. The paper was reviewed by Dr. B. H. Hogg, Dr. R. D. Connor and Dr. B. G. Whitmore of the University of Manitoba Department of Physics. Of the paper, Dr. Whitmore wrote:

> We are completely agreed that it represents a standard considerably higher than that of the present Grade XI.[7]

In June of 1963 at Regina, an Inter-Provincial P.S.S.C. meeting was held. This was attended by representatives from British Columbia, Alberta, Saskatchewan and Manitoba. The experience in Saskatchewan particularly seemed to reflect that of Manitoba where the success of the pre-pilot group had raised interest and enthusiasm among teachers and administrators.

The Manitoba Department of Education decided to conduct a pilot study and an expanded basis from pre-pilot group. This pilot study began in September 1963 at four High Schools. All students electing the Physics option in Grade

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[7] B. G. Whitmore, Professor and Head, Physics Department, University of Manitoba, in a letter, May, 1963.

XI, at Glenlawn Collegiate in St. Vital, Stonewall Collegiate in Stonewall, and Gordon Bell High School in Winnipeg, were given the P.S.S.C. course of study. Three of the six Grade XI physics classes at Grant Park High School were also given the P.S.S.C. course. The teachers involved had all taken the recommended special training, B. Unruh of Grant Park, A. Hammond of Stonewall and the writer of Gordon Bell had all attended summer N.S.F. institutes at Nebraska Wesleyan University while H. Pearce of Glenlawn had taken his training at the University of British Columbia.

During the next two years these four teachers met semi-monthly to plan their work, discuss common problems and evaluate their progress and at the end of this period, recommended unanimously that P.S.S.C. be introduced in to Manitoba schools on as broad a scale as possible.

In October 1963 the Department of Education appointed curriculum committees in several subject areas. The Physics Curriculum Committee under the chairmanship of Dr. R. D. Connor concurred in the recommendation of the P.S.S.C. pilot study group. The committee further specified that teachers offering the P.S.S.C. course should be required to take special training.

To meet the anticipated need of substantial numbers of specially trained teachers, the Faculty of Education at the University of Manitoba introduced a special course in methods of P.S.S.C. teaching. This course was first offered during the summer of 1964 and participants were given financial assistance by the International Nickel Company and the Department of Education. This course has to date been offered five times, either as a six week summer course or as a winter course of about twenty-five all day sessions held on Saturdays. About one hundred and fifty teachers have participated. Currently the Faculty is offering a P.S.S.C. methods course as an elective to the students in their first year of professional training and the need for special courses would therefore gradually diminish.

During the 1967-68 school year 80 teachers in Manitoba are involved offering the P.S.S.C. syllabus to 2,591 students at the Grade XI levels and 1,628 students at the Grade XII level.

III. AN OUTLINE OF THE P.S.S.C. PHILOSOPHY

Until 1961 physics teaching in Manitoba has in the main followed a traditional pattern of treating theory and laboratory as two separate entities. Despite the fact that many physics teachers attempted and in many cases succeeded in correlating the two so that the one complimented the other, the general practice seems to have been to teach the theory in the classroom and then when the opportunity presented itself this theory was verified in the laboratory by doing an experiment for which the result was already established. In most schools, a specified period for laboratory was assigned to each class and classes were given a laboratory exercise to perform at this time each week irrespective of what position of the theory was under study at that time. An even less desirable practice was followed in some smaller schools where laboratory equipment was in short supply. Here with only one or two sets of apparatus for each experiment, all experiments would be done on a rotational basis. Thus a student might be asked to do an experiment in light months before this area was to be treated in the theory section of the course.

Recognizing that the foregoing procedures were being followed, the Department of Education adopted the policy of granting separate standing in laboratory or Practical Physics and Physics Theory and a student could receive credit for one while failing in the other.

Adoption of P.S.S.C. as a course of study necessitates a departure from practice of treating laboratory and theory as separate entities. The philosophy of the P.S.S.C. approach requires the student to discover in the laboratory the physical relationships that he will use in the theory. To achieve this, it is obvious that a rigorous laboratory schedule cannot be adopted. Experiments must be performed at the appropriate times as dictated by progress of the class in their study of the theory. Also, sufficient equipment must be available to allow all students in a class to perform the same experiment at one time. In short, the practice of having anywhere from two to twenty different experiments performed on a rotational basis according to a preset schedule cannot be applied to the teaching of P.S.S.C. physics.

IV. A SYNOPSIS OF THE COURSE OF STUDY

The P.S.S.C. course of study is divided into four closely related and connected parts. The first of these is a general introduction to the understanding and measurement of the fundamental physical notions of time, space and matter.

> As the student learns of the almost boundless range of dimensions from the immensely large to the infinitesimally small, from microseconds to billions of years, he finds out how these magnitudes can be measured. He learns that instruments serve as an extension of his senses. Laboratory experience shows how we first measure by direct counting and then extend our range of measurements by calibrating and using simple instruments such as stroboscopes or range finders.[8]

After the experiments measuring space and time the student moves to the general study of functional relationships and their graphical analysis. He then uses these

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[8] P.S.S.C. Physics, D.C. Heath and Company, Boston, 1960, p.v.

techniques to study the displacement, velocity and acceleration relationships of relative motion and is introduced to vectors as a valuable tool to assist in this study. Throughout Part I, the student is exposed to the unity of Physics and the realization that it is a single subject of study in which concepts of time space and matter cannot be separated.

Having looked at the broad picture of the Universe in Part I, the P.S.S.C. course of study moves on to examine certain fields in more detail. Part II begins with the observation of the common phenomena associated with light, reflection and refraction. Based upon these experiences a particle model or theory is developed. The student is able to go beyond the high school laboratory in his scouting of this model by the use of 16 mm films on such topics as "Pressure of Light" and "Speed of Light". Finally the particle model proves inadequate and a wave model is suggested.

> The laboratory again provides an unexcelled source of experience, and here the student becomes familiar with the properties of waves. He observes the behaviour of waves on ropes and on the surface of water. He begins to recognize the group of characteristics that constitute wave behaviour. Knowledge of interference and diffraction comes directly from a study of waves in a ripple tank. For the first time, perhaps, the smears of light around street lamps, the colors of oil slicks, and the formation of images by lenses appear as aspects of the wave nature of light.[9]

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[9] Ibid.

In the third part of the P.S.S.C. course of study a closer observation of motion from a dynamical aspect is made. Simple laboratory apparatus provide the necessary means for the student to discover Newton's law of motion. The prediction of forces when motions are observed or motion when forces are known and revelation of Newton's intuition whereby he was able to formulate the law of Universal gravitation are followed by a study of the laws of conservation of movement and of energy. These in turn enable the student to appreciate the work of Chadwick in the discovery of the neutron or the kinetic theory of gases, where detailed observation of the motion involved is not possible.

Part IV introduces the student to electricity and through this to the physics of the atom. The measurement of very small electric forces is achieved using the knowledge gained from the dynamics of Part III. Simple laboratory apparatus enables the student to do a Millikan oil drop type experiment using microscopic plastic spheres and thus gain an appreciation of the grain-like nature of electric charge. The motion of charged particles in electric fields is studied and used to determine the masses of electrons and protons. A discussion of magnetic fields produced by magnets and by current electricity and the forces they exert on moving charges is followed by the induction laws.

With the knowledge thus gained the structure of the atom is probed and a nuclear model developed. Unanswered questions lead to the discovery that light is both granular and wavelike in nature and that by the combination of both properties, the stability of the Bohr model of the hydrogen atom and the structure of its energy levels is understood.

> In this part of the course, because direct experimentation becomes harder and more expensive, films bring to the student such experiments as the interference of photons. At the end of the course we have arrived at the modern model of atoms.[10]

V. A REVIEW OF EVALUATIVE INVESTIGATIONS

There has been to date no one major appraisal of the P.S.S.C. course made in the United States. This must not be taken to mean that the course has no critics, both at home in the United States and here in Canada too many have written articles pointing out its shortcomings. However, the machinery which the Committee set up whereby they obtain "feedback" from those people using the course materials has proven highly effective. This enabled much revision to be made of the early trial materials even before the publication of the first edition of the text. At present the Committee sponsors "area meetings" of teachers both in the U.S.A. and in Canada wherever there

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[10] *Ibid.*

are sufficiently large enough groups of teachers using P.S.S.C. to populate a meeting. These regular annual area meetings are designed to evaluate the course in the light of the direct experience of those using it and the evaluations are submitted to the Committee for information and often action through revision. In 1965 the second edition of the text appeared and embodied many changes which found their beginning with the teachers in their area meetings. The fact that the number of P.S.S.C. users continues to grow is testimony to the effectiveness of the Committees' program for revision.

In an investigation of high school physics achievement, Marlow A. Market[11] attempted to compare the relative effectiveness of the traditional high school curriculum and the physics curriculum developed by the Physical Science Study Committee. The experimental results are reported in an article by Warren L. Hipsher.[12]

> Students taught physics using the traditional high school physics curriculum performed significantly better on the Cooperative Physics Test than students

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[11]Marlow A. Market, "Study of High School Physics Achievement," Thesis for D. Ed. degree, University of Tulsa, Tulsa, Oklahoma, 1960.

[12]Warren L. Hipssher, "Study of High School Physics Achievement," <u>The Science Teacher</u>, October, 1961, pp.36,37.

taught high school physics using the curriculum developed by the Physical Science Study Committee.

In reaching this conclusion, four variables were statistically controlled, scholastic aptitude as measured by the Gamma Form of the Otis Quick-Scoring Mental Ability Test, prior achievement in natural science as measured by Form YZ of the General Achievement Test in Natural Science, physical science aptitude as measured by the Physical Aptitude Test and Socio-economic status as measured by the North Hatt Scale.

In Market's study two all male samples of nearly equal size were used, one being a control group and the other an experimental group, and the null hypothesis that there is no difference in the mean achievement of the control and experimental groups in their response to the criterion, the Cooperative Physics Test was rejected, and it was further concluded that the control group mean exceeded that of the experimental groups by at least 6 points, a margin equal to one-half the standard deviation of either group.

Hipsher[13] points out that the criterion is acknowledged to be a traditionally oriented test and is based upon syllabi of the College Board Entrance Examination Committee and the New York Board of Regents' Examination.[14] He further

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[13] Ibid.

[14] Oscar K. Buros. The Nineteen Forty Mental Measurements Yearbook, Braunworth and Company, Inc., Bridgeport, Conneticut, 1941.

states:

> As a result of the choice of this particular criterion, the students in the control group may have had an advantage over the students in the experimental group. If such an advantage did exist because of the selection of this particular criterion, then the results of this investigation would be biased in favor of the control group.

In essence then, Market's study does not undermine the value of P.S.S.C. as a good course for the study of physics but raises the serious question as to its effectiveness in the preparation of high school students for success in a traditional physics curriculum undertaken as part of their post-secondary education. Assessment of this possibility and of the natural outgrowth of it, the necessity for reorientation of college and university physics departments to the objectives of the P.S.S.C. course of study, are not within the scope of this study.

Assessments of P.S.S.C. have been made in various Canadian provinces. In Ontario at Carleton University the P.S.S.C. course was first offered to 90 students entering the qualifying physics year. These students all had high standing in the Ontario Junior Matriculation examinations and would have entered, had they not entered the qualifying year, the ordinary Grade XIII of the senior matriculation academic course. The instructor held a Master's degree in physics but had no teacher training and substantially no experience. In assessing Carleton's experience Dr. John Hart[15], chairman of the Physics department admitted that Carleton had failed the P.S.S.C. course and not vice versa. It was concluded that the course was not suitable for the university's purposes but its wide adoption at a lower level was strongly advocated. P.S.S.C. has since been adopted as the course of study for Grade XIII students who have had prior training in physics in traditional courses.

In British Columbia the committee of teachers and university professors headed by Dr. Livsey, himself a contributor to the P.S.S.C. program, has formed a three year course in which P.S.S.C. plays a major role along with other materials written specially for that province by members of Dr. Livsey's committee.

The first P.S.S.C. work in Alberta began in the 1961-62 school year with 4 Grade XII and 6 Grade XI classes. This was expanded the following year to 10 Grade XII and 8 Grade XI classes. Most of the classes were held in schools in the Edmonton area and the report from teachers involved in this experiment was qualified but favourable.

Saskatchewan has attempted to adopt P.S.S.C. and its

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[15] John Hart, "Is the P.S.S.C. Course Suitable for Canadian High Schools?" Appendix B.

development there closely parallels the experience in Manitoba. Professor Stanley Clark of the College of Education, University of Saskatchewan analyzed test scores for a large group of students in Grade XI at ten different high schools. The tests used were the Tests of the Physical Science Committee numbers 1, 3, 4 and 5. The scores were compared with the publisher's norms and the sample was described in terms of I.Q. based upon results obtained from the Gamma Form of the Otis Quick-Scoring Mental Ability Tests. Professor Clark merely reported these data to the teachers participating in the experiment without drawing any conclusions.

CHAPTER III

EXPERIMENTAL DESIGN

In measuring the suitability of P.S.S.C. as defined in Chapter I, the initial work of this investigation was devoted to the evaluation of student achievement.

In September 1963, four teachers began the Manitoba pilot study of P.S.S.C. with 261 Grade XI students enrolled in eight classes. This group was selected as the sample to be examined by this study. It was examined and found to contain groups from urban, suburban and rural areas. The urban area was represented by groups at two schools. Three classes totalling 97 students at Grant Park High School and two totalling 71 students at Gordon Bell High School, both in the Winnipeg School Division. The suburban area was represented by two classes in Glenlawn School, St. Vital in which 61 students were enrolled while Stonewall Collegiate had one class of 32 students which represented the rural setting.

In an attempt to eliminate bias from the sample, all students electing physics as a Grade XI option in Glenlawn, Gordon Bell and Stonewall were given the P.S.S.C. course. This was not possible at Grant Park school because of the large number of students electing the Physics option with only one teacher available with the special P.S.S.C. training required to teach the course.

The result of either the Dominion or the Otis mental ability test was available for almost all students in the sample and from this an intelligence quotient was obtained.* These quotients were used to assign students to one of four categories, A, B, C or D. Group A were those having an I.Q. of 120 or over. Group B were those from 110 to 119. Group C had quotients from 100 to 109 and group D were those whose I.Q. was below 100. The frequency in each category was then determined and compared to the total to establish the percentage distribution.

Test #1 and #3 of the Tests of the Physical Science Study Committee Series O[1] were administered to the students comprising the Grade XI sample. These tests cover that portion of the P.S.S.C. course assigned for Grade XI. The results of these tests were then compared with the norms furnished by the publisher which were obtained using students in the United States of America.

In September 1964 the Grade XII portion of this evaluative study was begun. Of the original 261 students, 195 elected to continue their study of physics and composed the bulk of the sample for our evaluation. They were joined

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*Intelligence quotients obtained from these two sources while not identical are known to be very nearly equal.

[1]Educational Testing Service. Tests of the Physical Science Study Committee. Prinston, N.J. 1959. Appendix C.

by 10 newcomers to the course. Although some had taken a conventional physics option in Grade XI, none had studied P.S.S.C. before. The distribution of I.Q. scores for these 205 students was examined in the same manner as the Grade XI sample. They were administered tests numbers 4, 5, 6 and 7 of the same Educational Testing Service series[2] and the results again were compared to the American norms. It is worthy of note that four test items both on test 5 and test 7 were judged unsuitable and excluded since they covered material from Chapters 7, 8, 9 and 26 of the text[3] which were omitted from the course of study for Manitoba. Since these tests contained 35 items each, and all items are of equal value, the 45 minute test period was proportionately reduced by 5.1 minutes to maintain the same time allowance per test item given in the original tests.

By September 1967, 80 teachers in Manitoba were engaged in the instruction of physics using the P.S.S.C. syllabus. Assessment of their acceptance of the P.S.S.C. course, in determining its suitability for use in Manitoba, was deferred until late in April in order to give those teachers in their first year of P.S.S.C. as much experience with the course as possible. To measure teacher acceptance, the Likert Method of Summated Ratings was chosen. Edwards

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[2] Ibid.

[3] P.S.S.C., op.cit.

and Kenney[4] found the Likert scale to have a high correlation of +.92 with the Thurstone Technique of scaled values[5] but the latter has the disadvantage of requiring the statements to be submitted to a panel of fifty or more judges for scaling before they are administered to the group.

In the construction of the Lickert scale, 34 statements about P.S.S.C. were chosen as representing opinions held by a substantial number of educators. The statements were eventually divided as in favour of and against the course or its related materials. These statements were then submitted to a panel of two judges both of whom were known to be very favorably inclined toward P.S.S.C. Both judges responded independently to each statement by indicating one of the following five categories: (a) I agree with the statement; (b) I am inclined to agree (with reservations); (c) I cannot say (have no feeling one way or another) (the evidence is insufficient); (d) I am inclined to disagree (disagree with reservations); (e) I disagree with the statement. The statements were assigned values of 1 up to 5 or 5 down to 1 in such a manner that a high score on an item

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[4]Allen L. Edwards and Katherine C. Kenney, "A Comparison of the Thurstone and Lickert Techniques of Attitude Scale Construction," Journal of Applied Psychology, February 1946, pp.72-83.

[5]L. L. Thurstone and E. J. Chane, The Measurement of Attitudes, (Chicago: University of Chicago Press, 1929).

indicated a favorable inclination to P.S.S.C. and a low score indicated dissatisfaction with or opposition to P.S.S.C.

The judges' scores on each item were combined giving each item a minimum value of 2 and a maximum value of 10. The thirty items having a combined score of 7 or greater were regarded as suitable and were retained to form a P.S.S.C. Teacher Opinionnaire. (Appendix D). Three items having a combined score of 6 were regarded as unsuitable since they indicated no opinion, or a disagreement between the judges. One item having a combined score of 5 was discarded since it represented a conflict of opinion between the judges.

The opinionnaires were sent to all the teachers in Manitoba who were using the P.S.S.C. syllabus and 80% of them were returned. The responses which were received from these 64 teachers were then scaled and totalled to determine the teacher's attitude.

The individual items on the opinionnaire were divided into groups in accordance with which of the following areas of the P.S.S.C. they sampled (1) the textbook, (2) the laboratory materials, (3) the films, (4) the P.S.S.C. philosophy, or (5) miscellaneous. The 64 opinionnaires were then analyzed in each of the first four of these areas.

CHAPTER IV

ANALYSIS OF FINDINGS

I. STUDENT ACHIEVEMENT

In considering the performance of Manitoba students as an aspect of the suitability of the P.S.S.C. syllabus, some attention must be given to the sample of students used in the investigation. Statistically speaking, the sample used was not random since all Manitoba students electing the physics option did not have an equal opportunity of being selected. By definition, a representative sample is

> ...one in which the distribution of scores in the sample closely parallels that of the population.[1]

Since the offering of the P.S.S.C. syllabus to students requires specially trained personnel it was impossible to select the sample of students for the investigation on either a random or a representative basis. Instead, the sample was selected by classes from urban, suburban and rural schools in Manitoba and all students in each class selected followed the P.S.S.C. syllabus.

The distribution of intelligence quotients of the sample as reported in Tables I and II shows a skewness

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[1]Henry E. Garrett, Statistics in Psychology and Education, (David McKay Company Inc., New York, 1962.) p.203.

TABLE I

DISTRIBUTION OF I.Q. FOR MANITOBA GRADE XI SAMPLE

Group	I.Q. Range	No. of Students	Per Cent Distribution
A	120 and above	114	42.1
B	110 - 119	75	27.7
C	100 - 109	35	12.9
D	Below 100	25	9.2
E	unknown	22	8.1

TABLE II

DISTRIBUTION OF I.Q. FOR MANITOBA GRADE XII SAMPLE

Group	I.Q. Range	No. of Students	Per Cent Distribution
A	120 and above	94	45.8
B	110 - 119	62	30.2
C	100 - 109	24	11.7
D	Below 100	13	6.3
E	unknown	12	6.0

favoring the above average intelligence groups. Such a distribution would be expected in an examination of any group of students in the university entrance stream of the high school population and particularly in the case of physics which has the reputation of being one of the more difficult subject options. Table III shows the frequency distribution of raw scores of Manitoba students on the six Educational Testing Service standardized P.S.S.C. tests. The maximum raw score on all tests is 35; however, this maximum was reduced to 31 for Manitoba students in tests number 5 and number 7 since four of the 35 items were deleted. These deletions were made because the material examined in the items was from chapters not included in the Manitoba P.S.S.C. curriculum. In order to compare these test scores with the United States norms, they were scaled on the basis of simple proportion and all the ensuing statistical data quoted for these tests are the scaled values.

In measuring the significance of the difference between two means, the most direct method would be to compute the critical ratio.[2] To compute this ratio, the number of individuals in each sample must be known. This number

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[2]Henry E. Garrett, Elementary Statistics, (Longmans Green and Company, New York, 1956.) pp.94-100.

TABLE III

DISTRIBUTION OF RAW SCORES OF MANITOBA STUDENTS ON P.S.S.C. TESTS

	Frequency Distribution					
Raw Score	Test 1	Test 3	Test 4	Test 5	Test 6	Test 7
32	2	-	-	-	-	-
31	2	1	-	-	1	-
30	1	-	1	-	3	-
29	1	1	2	1	2	3
28	7	2	1	-	4	1
27	6	3	3	2	1	2
26	5	1	4	1	5	4
25	10	5	6	1	4	8
24	7	7	5	2	5	3
23	6	7	11	1	9	4
22	14	15	11	7	12	10
21	11	15	10	5	10	14
20	20	17	16	8	14	11
19	18	19	17	11	11	17
18	21	16	15	15	18	15
17	27	13	17	26	14	13
16	18	26	8	12	18	17
15	26	21	15	19	13	15
14	20	19	8	13	4	14

continued

TABLE III CONTINUED

Raw Scores	Frequency Distribution					
	Test 1	Test 3	Test 4	Test 5	Test 6	Test 7
13	13	14	8	21	13	7
12	10	8	9	18	6	9
11	5	5	6	9	6	11
10	3	8	11	14	10	5
9	1	3	5	4	3	4
8	3	3	2	7	2	6
7	-	1	1	1	1	-
6	1	2	1	1	-	-
5	-	1	1	1	-	-
4	-	-	-	-	-	-
3	-	-	-	-	-	-
2	-	-	-	1	-	-

was known for the sample of Manitoba students, but because of the manner in which the United States norms were established, the publisher of the P.S.S.C. test could not provide this information for students in the United States. For this reason, the comparison of the performance of the two groups of students has been made by computing the standard error of the means for the Manitoba sample and establishing upper and lower confidence limits at the 95% and 99% levels. (Table IV).

The means of the E.T.S. test scores for the United States sample (Table V) were then inspected to determine where they fell in relation to these limits..

The inspection or comparison of these means shows that there is no significant difference in the means of the Manitoba and United States samples for tests number 3, 4 and 5. For test number one, while the mean score for the Manitoba students is higher than the U.S. mean score, it does not lie outside the 99% confidence limit. Therefore no significant difference in performance can be concluded as existing between the Manitoba and United States samples on these four tests.

In discussing the use of this technique of comparison, Garrett[3] states that:

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[3]Garrett, Op.Cit. pp.188-189.

TABLE IV

CONFIDENCE LIMITS FOR THE MEANS OF MANITOBA STUDENTS ON THE P.S.S.C. TESTS

	Lower Confidence Limits		Calculated	Upper Confidence Limits		
	99%	95%	Mean	95%	99%	U.S.
Test No.	$-2.58\sigma_M$	$-1.96\sigma_M$	Manitoba Sample	$+1.96\sigma_M$	$+2.58\sigma_M$	Mean
1	17.39	17.57	18.16	18.75	18.93	17.5
3	16.47	16.65	17.24	17.83	18.01	17.5
4	16.63	16.85	17.58	18.31	18.53	17.5
5	16.22	16.42	17.07	17.72	17.92	17.5
6	17.02	17.24	17.97	18.70	18.92	21.0
7	18.53	18.77	19.51	20.25	20.49	18.0

TABLE V

STANDARD DEVIATIONS AND SEMI-INTERQUARTILE RANGES FOR UNITED STATES AND MANITOBA SAMPLES.

Test No.	U.S.	MAN.	U.S.	MAN.
1	5.0	4.8	3.5	3.2
3	5.0	4.6	3.5	3.1
4	5.0	5.1	3.5	3.5
5	5.0	4.7	3.5	2.8
6	5.5	5.0	4.0	3.4
7	5.5	5.3	4.0	3.3

...Description of the stability of a sample mean in terms of "probable divergence of statistic from parameter"...it is evident that confidence can be placed in a sample mean if there is small likelihood of its having missed its population value by a large amount.....estimating the M_{pop} through the setting up of limits which for a given degree of confidence will embrace the population mean. Such limits are said to be confidence intervals....

Garrett[4] further explains that

Whether a difference is to be taken as significant or not depends upon the probability that it could have arisen by chance. The probability is .95 that the population mean lies within the interval of $M \pm 1.96$ M and .05 that it falls outside these limits. Similarly it is .99 that it lies within $M \pm 2.58$ M and .01 that it falls outside this range.

Experimenters and research workers have for convenience chosen arbitrary standards...of which the .05 and .01 levels are most often used.[5]

Referring again to Table IV, examination of the limits for test number 6 showed that the estimated mean of 21.0 for the United States sample lay outside the 99% upper confidence limit of 18.92 established for the Manitoba sample. Also, for test number 7 the estimated mean of 18.0 for the United States sample was outside the 99% lower confidence limit of 18.53 of the Manitoba sample. Further reference to the differences indicated by the positions of these two means will be made in the next chapter.

Having examined and compared the means of the six tests

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[4] *Ibid.*, p.191.

[5] *Ibid.*, p.216.

as a measure of the central tendency of the performances of the United States and Manitoba students, a further dimension, the variability, was examined. For this purpose both the standard deviation and the semi-interquartile range (Table V) were computed[6] for the Manitoba sample and compared to those of the United States sample. Inspection of the values in this table showed little difference between the two samples. The frequency distribution of the Manitoba sample shown in Table III indicated a normal type of distribution in all six tests. Further evidence of the similarity of the two samples was found when their percentile norms were compared (Table VI). This inspection was considered necessary to ensure the absence of sufficient skewness or kurtosis to alter the relationships assumed[7] in using the standard deviation as a measure of variability. The conclusion drawn from the inspection of the measures of variability was that the Manitoba sample had a slightly more peaked or leptokurtic[8] distribution than did the United States sample in all tests. The degree of difference however was insufficiently large to conclude any marked difference between the groups.

II. TEACHER ACCEPTANCE

The second aspect of the suitability of P.S.S.C. for use

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[6] Garrett, Op.Cit. pp.50-51.

[7] Palmer O. Johnson and Robert W.B. Jackson, Introduction to Statistical Methods, (Prentice-Hall Inc., New York, 1953), p.151.

[8] Garrett, Ibid., p.87.

TABLE VI

COMPARISON OF NORMS FOR UNITED STATES AND MANITOBA SAMPLES ON THE P.S.S.C. TESTS

%tile	Test #1		Test #3		Test #4		Test #5		Test #6		Test #6	
Norm	U.S.	MAN.	U.S.	MAN.	U.S.	MAN.	U.S.	MAN.	U.S.	MAN.	U.S.	MAN.
90	24.0	25.3	24.0	23.0	24.0	23.7	24.0	22.5	28.0	24.8	25.0	26.6
75	21.0	21.2	21.0	20.4	21.0	21.1	21.0	19.4	25.0	21.4	22.0	22.6
50	17.5	17.6	17.5	16.7	17.5	17.8	17.5	16.4	21.0	17.8	18.0	18.8
25	14.0	14.8	14.0	14.2	14.0	14.1	14.0	13.2	17.0	14.7	14.0	15.2
10	11.0	12.7	11.0	11.5	11.0	10.4	11.0	10.6	14.0	11.0	11.0	11.7

in Manitoba as defined in this investigation was the acceptance by teachers of the course. The following analysis is based upon the response of teachers to the opinionnaire circulated to all Manitoba teachers using the P.S.S.C syllabus in the school year 1967-68. Replies were received from 64 of the 80 teachers involved and hence the analysis represents the opinion of 80% of the Manitoba teachers using the P.S.S.C. methods and materials. To measure the teacher acceptance of P.S.S.C. the Likert scaling technique was employed. Starting from the point of view of acceptance of P.S.S.C., all statements favoring this point of view were scored or given a scaled value as in Table VII with agree being assigned a value of 5, and statements opposing the point of view were scored as in Table VIII with agree being assigned a value of one. The opinionnaire used contained 30 items as did the example cited by John W. Best who states that:

> The test scores obtained on all of the items would then measure the respondent's favorableness towards the given point of view. If the opinionnaire consisted of 30 statements or items, the following score values would be revealing:
>
> 30 x 5 = 150 -- most favorable response possible
> 30 x 3 = 90 -- a neutral attitude
> 30 x 1 = 30 -- most unfavorable attitude
>
> The scores for any individual would fall between 30 and 150; above 90, if opinions tended to be favorable, and below 90, if opinions tended to be unfavorable to a given point of view.[9]

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[9]John W. Best, Research In Education, (Prentice-Hall Inc., New Jersey, 1965.) pp.158-59.

TABLE VII

SCALED SCORE ASSIGNMENT TO OPINIONNAIRE STATEMENTS FAVORING P.S.S.C.

Teacher Response	Assigned Score
Agree	5
Agree (with reservations)	4
Cannot say	3
Disagree (with reservations)	2
Disagree	1

TABLE VIII

SCALED SCORE ASSIGNMENT TO OPINIONNAIRE STATEMENTS OPPOSING P.S.S.C.

Teacher Response	Assigned Score
Agree	1
Agree (with reservations)	2
Cannot say	3
Disagree (with reservations)	4
Disagree	5

The distribution of teacher opinionnaire scores shows a marked skewness in favor of P.S.S.C. (Table IX). Of the 64 responding, 59 had total scores of 99 or greater indicating varying degrees of favor. Four had total scores between 87 and 94 indicating a neutral position. One teacher had a total score of 59 indicating strong opposition. The median score of all teachers was 119 and 44% of the teachers indicated their highly favorable inclination toward the course by scoring 120 (an average of 4.0 per item) or greater.

TABLE IX

GROUPED DISTRIBUTION OF TOTAL SCORES ON P.S.S.C. TEACHER OPINIONNAIRE

Interval	Frequency
140 - 149	1
130 - 139	7
120 - 129	20
110 - 119	22
100 - 109	9
90 - 99	2
80 - 89	2
70 - 79	-
60 - 69	-
50 - 59	1
40 - 49	-
30 - 39	-

To analyze the individual items on the opinionnaire, the frequencys of each assigned score or scaled value were tabulated for each item (Table X) and the item's mean score was found. This analysis showed 17 items, or 57% of the opinionnaire as having a mean response of 4.0 or greater. All items except numbers 6 and 23 reflected a favorable attitude towards P.S.S.C., having mean scores of 3.2 or greater. The response to item 6 indicated a strong feeling among teachers that P.S.S.C. could not be used successfully with students of the General course stream in Manitoba high schools. The response to question 23 showed that teachers felt that P.S.S.C. was not successful in stimulating the students to read outside the course of study.

Twenty five of the opinionnaire items were assigned as they referred to one of four categories: (1) Subject matter, methods and philosophy, (2) Films, (3) Laboratory, and (4) Textbook as shown in Table XI. This analysis indicated no significant difference in attitude of teachers towards the areas examined. In the category of films many teachers wrote in comments on the opinionnaire indicating their dissatisfaction with the availability of the films for use when desired. The scores of these teachers were responsible for the films being slightly lower than the other categories. Further reference to the degree of teacher acceptance will be made in the next chapter.

TABLE X

FREQUENCY OF TEACHER RESPONSES TO OPINIONNAIRE ITEMS

Item No.	Scaled Value Frequency					Mean Score
	1	2	3	4	5	
1	2	2	1	27	32	4.3
2	0	4	6	14	40	4.4
3	5	4	23	27	5	3.4
4	2	10	4	16	32	4.0
5	4	5	3	11	41	4.3
6	37	16	1	9	1	1.8
7	3	0	5	14	36	4.4
8	2	3	3	18	38	4.4
9	4	14	10	20	16	3.5
10	4	18	3	20	19	3.5
11	7	7	23	17	10	3.3
12	3	21	9	20	11	3.2
13	7	10	6	17	24	3.6
14	3	7	21	14	19	3.6
15	7	9	15	19	14	3.4
16	1	0	6	12	45	4.5
17	2	6	6	21	29	4.1
18	4	10	3	12	35	4.0
19	2	3	1	11	47	4.5
20	4	5	3	23	29	4.1

Continued

TABLE X CONTINUED

Item No.	Scaled Value Frequency 1	2	3	4	5	Mean Score
21	1	7	2	21	33	4.2
22	1	2	9	20	32	4.3
23	19	23	6	13	3	2.3
24	4	12	4	26	18	3.7
25	0	0	6	18	40	4.7
26	1	14	1	24	24	3.9
27	0	1	9	23	31	4.3
28	3	1	7	8	25	4.4
29	2	2	3	19	38	4.4
30	6	14	1	26	17	3.5

TABLE XI

ANALYSIS OF TEACHER ATTITUDE TO OPINIONNAIRE SUB-AREAS

Sub-Area	No. of Items	Mean Score
Subject matter Methods & Philosophy	14	4.1
Films	6	3.7
Laboratory	5	4.2
Textbook	5	4.0

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

In this investigation the suitability of the P.S.S.C. syllabus for use in Manitoba high schools was examined. To be suitable it was decided that the P.S.S.C. course must be of an appropriate level of difficulty for the students who will study it, and also be acceptable to the teachers who must offer the instruction in it.

The P.S.S.C. course was developed in the United States for use with high school students in that country, and before making its appearance in published form, it was subjected to many modifications deemed advisable by the wide experience of the many teachers participating in its development. The assumption was made that as a result of this intensive evaluation and modification the resulting course was of the appropriate level of difficulty for students in the United States. If then the students in Manitoba studying this physics course achieved as well as the students in the United States, the course could be considered to be suitable for them.

To measure and compare this achievement, a series of six objective tests were administered to groups of students in the two countries. The mean score of the students on each of these tests was examined to see if there was any significant difference between the performance of the United States and the Manitoba students.

Means for the United States sample of students were furnished by the Educational Testing Service, publisher of the P.S.S.C. tests. To establish achievement means on the tests for Manitoba students, a sample of 262 Grade XI and 205 Grade XII students was selected for examination. These students followed the P.S.S.C. course of study instructed by four teachers who had taken special training in this technique. The P.S.S.C. tests were administered to this sample of Manitoba students and the mean score for each test was found and compared to the corresponding United States mean score.

To measure the attitude of teachers toward the P.S.S.C. syllabus, a teacher opinionnaire was devised, validated by a panel of judges, and circulated to all teachers in Manitoba offering the P.S.S.C. course during the 1967-68 school year. The opinionnaire was of the type utilizing the Lickert method of summated ratings. Each of the 30 items on the 64 opinionnaires which were returned by the teachers was scored on a 5 point scale in such a manner that a high score showed a high degree of acceptance and a low score showed rejection of the item. The teacher's total score was taken as a measure of his overall acceptance or rejection of the course. The mean score of all teachers on each item was found and a measure of the attitude of teachers toward (1) the textbook, (2) the laboratory materials, (3) the films, and (4) the P.S.S.C. philosophy was obtained by examining the items of the opinionnaire under these categories.

II. CONCLUSIONS

In assessing the suitability of the course from the standpoint of student achievement, it was found that in four of the six tests given, no significant difference existed between the mean score of the United States sample and that of the Manitoba sample. Further, it was found that in five of the six tests given, the Manitoba students achieved at a level equivalent to or better than the students from the United States. This evidence strongly supports the conclusion that the level of difficulty of the course is appropriate. In other words, the P.S.S.C. course of study is suitable for use with similar groups of Manitoba students.

The evidence of teacher's reaction to the P.S.S.C. course shows a high degree of acceptance. Replies were received from 80% of the P.S.S.C. teachers in Manitoba. With the mean score per item of half of these teachers being 3.97 or greater, it is safe to conclude that there is a high level of acceptance of P.S.S.C. among those teachers who have experience using it in Manitoba. The teachers showed strong acceptance in each of the four areas investigated; the textbook, the laboratory materials, the films and the philosophy. Only three of the 64 teachers responding to the opinionnaire showed any rejection of the P.S.S.C. syllabus and two of these were very close to the "no opinion", 90-score area, having total scores in the 80-89 range.

From these data it can be concluded that the P.S.S.C. syllabus is accepted by Manitoba teachers.

In the first chapter, suitability was defined as the course first being acceptable to teachers and secondly being of an appropriate level of difficulty such that if used by Manitoba students, their achievement would equal that of the students in the United States. This investigation has shown that the P.S.S.C. course is suitable as defined, for use with the students in the University Entrance course in Manitoba high schools who choose physics as one of their optional subjects.

III. IMPLICATIONS

This investigation made no attempt to evaluate the articulation of P.S.S.C. students in university courses as compared to that of students studying physics in a traditional manner. Since one of the objectives of the study of physics by students in the university entrance course is to prepare them for further studies in the field of physics at the university, such an evaluation would yield valuable information, and should be undertaken.

No provision was made in this investigation to differentiate between the success of male students as compared to that of female students. The teachers opinionnaire revealed only a slight agreement with the statement of item number 11 which suggests that P.S.S.C. seems to eliminate any advantage that was held by boys studying traditional physics over girls in the same course. The evidence is not strong enough to merit a conclusion, but suggests that the advantage to male students may be reduced by P.S.S.C. course.

The experimental results reported for tests #6 and #7 show the mean score of the United States sample to be significantly higher than the mean score for the Manitoba sample in test #6 while the reverse is true in test #7. This inconsistancy of performance suggests several possibilities that are worthy of further investigation.

In Manitoba, Chapters 7, 8 and 9 of the P.S.S.C. syllabus are deleted because they deal with subject matter that is normally covered in the chemistry courses. The possibility exists that the United States students, having studied these chapters, are more experienced with the P.S.S.C.

method and are hence able to perform at a higher level.

This fact would seem to be contradicted by the higher level of performance of the Manitoba students on test #7. In examining the possible explanations for this, the most obvious seems to be the difference in techniques of evaluation for the course. In Manitoba, with the sample used in this investigation, it was decided to forego coverage of the last three chapters in the course in favor of a higher level of mastery of the earlier portions. This decision was deemed necessary since all the Grade XII students in any subject area, P.S.S.C. included, must sit for a common examination in that area. These examinations are set externally by a subject committee appointed by the High School Examination Board. In the United States, however, it is more often left to the individual schools concerned to establish final grades and award standings. For this reason teachers in the United States have been free to adopt the philosophy of teaching the entire course rather than to concentrate on reaching an agreed upon level of mastery. Perhaps the higher performance of the Manitoba sample on test #7 is explained by this difference in philosophies.

Another of the factors which should be the subject of further investigation in an attempt to account for the differences in performance of the two groups on tests #6 and #7 is the grade level of the students. In Manitoba, the P.S.S.C. syllabus is split into a two year course for Grades XI and XII whereas in the United States, it is a one year course usually taken at the Grade XI level. This must not be taken to mean that the total time allotment in Manitoba is double that of the United States, but there are in fact more hours of instruction in Manitoba which might prove to be an advantage. Then too an advantage might arise from a better mathematical background, if such a difference existed. Further investigation would have to be made to determine the levels of the two samples and to ascertain the effect any difference could produce on their performance in P.S.S.C. physics.

The pressure of an external final examination and its effect upon the performance of students during the school year is another possible factor worthy of investigation in any attempt to account for the differences in performance between the two groups on tests #6 and #7. It is perhaps not unrelated to the difference in philosophies mentioned earlier, but is nonetheless important.

In Manitoba at the time of the investigation Grade XI accreditation of students was possible in certain high schools. The four high schools involved in the experiment were among those having this priviledge, and the majority of students involved in the study qualified for exemption from sitting for the final examination. During the Grade XI phase of the investigation then, for the majority of cases, the techniques for final evaluation employed in the United States and in Manitoba were highly similar in nature, and no significant difference in performance between the two groups was detected. However, during the Grade XII phase of the investigation when the entire Manitoba group faced an externally set final examination and the United States sample did not, significant differences in performance were found.

These observations suggest the need for further investigation into the evaluative techniques employed to ascertain whether or not there is a causal relationship between them and the performance differences detected by this investigation.

Previous mention has been made of the fact that teacher acceptance of the films as measured by the opinionnaire while very high, with a mean item score of 3.7, was lower than the other three categories examined. One possible accounting for this slightly lessor degree of acceptance is the availability of the films. In spite of the fact that no provision was made in the opinionnaire to express an attitude towards the distribution of the films, or whether they were available when desired, 16% of the teachers responding wrote in comments expressing dissatisfactions with the availability of the films. This evidence strongly suggests the need for an investigation into alternative methods for distribution of the films in Manitoba or a study of the feasibility of the utalization of television and video tape as a means of making the films available when required.

Item #6 of the opinionnaire, with a mean score of 1.8, indicated a very strong feeling among the teachers that P.S.S.C. could not be successfully used with students in the General Course. Some teachers qualified their position by writing in the comment that it was not suitable under the present system of evaluation by an externally set examination. Before the conclusion can be drawn that P.S.S.C. is not suitable for use with General Course students, it would be necessary to have data obtained from an experiment offering P.S.S.C. to a sample of such students.

The responses to item #23 of the opinionnaire indicated that there is a strong feeling among teachers that the P.S.S.C. course fails to stimulate in students the interest required to make them want to read outside the course of study. Further investigation is needed before any conclusion of weakness on the part of the P.S.S.C. course can be drawn. It is possible that the high school students of today have their free time heavily committed to other activities and are unable to persue all the interests that are aroused within them. It would be of value to survey the reading done outside the course of study by students following the traditional course.

This investigation has shown that students in Manitoba studying the P.S.S.C. syllabus have similar achievement to those studying it in the United States and it has further shown that the P.S.S.C. syllabus is highly accepted by the teachers in Manitoba. The investigation has not however considered sociological factors which may be operating to mitigate against any course in producing the desire in students to do extra reading. Further investigation might reveal that extra reading is a behavioral characteristic confined to the group who have already made a decision to persue a career in some field of physics.

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APPENDIX

APPENDIX A

MANITOBA P.S.S.C. SYLLABUS 1963-64

APPENDIX

UNIVERSITY ENTRANCE COURSE

PHYSICS 200 P.S.S.C. COURSE - (2 yr. course)

Pilot Classes 1963-64

Time Allotment : 12% or 190 minutes/week (approx.)

Text: Physics: D.C. Heath, Boston.

References: Science Study Series: Doubleday, New York.

Course Content: Chapters 1-6, 10-16.

Films: Time and Clocks, Long Time Intervals, Short Time Intervals, Measuring Large Distances, Measuring Short Distances, Change of Scale, Straight Line Kinematics, Vectors, Vector Kinematics Measurement, Introduction to Optics, Pressure of Light, Speed of Light, Simple Waves, Sound Waves in Air.

Laboratory Equipment - see appended sheet 2 year course.

Laboratory Experiments:

1-1	1-5	2-4
1-2	2-1	2-5
1-3	2-2	2-6
1-4	2-3	2-7

UNIVERSITY ENTRANCE COURSE

PHYSICS 300 PSSC COURSE - (2 yr. course)

Pilot Classes 1964-65

Time Allotment 16% or 250 minutes/week (approx.)

Texts - Same as for Grade XI

References - Same as for Grade XI

Course Content - Chapters 17-25, 27-32.

Films - Sound Waves in the Air, Forces, Inertia, Inertial Mass, Free Fall and Projectile Motion, Deflecting Forces, Period in Motion, Frames of Reference, Universal Gravitation, Elliptic Orbits, Elastic Collisions and Stored Energy, Energy and Work, Coulomb Law, Millikan Experiment, Coulomb's Force Constant, Electric Fields, Electric Lines of Force, Counting Electrical changes in Motion, Elementary Changes and Transfer of Kinetic Energy, E.M.F, Electrical Potential Energy and Potential Difference (Parts 1 and 2), A Magnet Laboratory, Electrons in a Uniform Magnetic Field, Mass of the Electron.

Laboratory Equipment - see appended sheet 2 year course.

Laboratory Experiments -

2-8	3-1	3-11
2-9	3-2	3-12
2-10	3-3	3-13
2-11	3-4	3-14
2-12	3-5	4-1
2-13	3-6	4-2
2-14	3-7	4-3
2-15	3-8	4-4
2-16	3-9	4-5
2-17	3-10	4-6
		4-7
		4-8
		4-9

P.S.S.C. APPARATUS FOR GRADE XI

Required for a class of 32 students.

Quantity	Item	Unit Price	Total Price
4	Microbalance	1.92	7.68
16	Hand Stroboscope	1.20	19.20
16	Distance Measuring Kit	4.56	72.96
16	Recording Timer	5.28	84.48
16	Optics Materials	5.52	88.32
5	Refraction of Particles	2.95	14.85
8	Wave Demonstrators	5.10	40.80
8	Ripple Tank	27.00	216.00
8	High Power Light Source	4.75	38.00
1	Molecular Layers	1.70	1.70
30	C-Clamps (3")	.93	27.90
1	Spectral Analysis Kit	5.90	5.90
			$617.79
	OPTIONAL		
1	Polaroid Land Camera		107.50
1	Micrometer Caliper		12.00
1	Motor Stroboscope Kit		8.28
30	Cornell Diffraction Slits*		45.00
			$172.78

Science Study Series.

* Obtainable from The National Press,
Palo Alto, California.

GRADE XII - Required for a class of 32 students

Quantity	Item	Unit Price	Total Price
Course Section III			
8	Dynamics Apparatus	9.60	76.80
8	Inertial Balance Set	3.80	30.40
16	Centripetal Force Apparatus	1.32	21.12
16	Collision in two dimensions	1.92	30.72
8	Potential Energy Apparatus	3.05	24.40
Course Section IV			
1	Macalaster Electrostatic Kit	10.00	10.00
1	Potential Difference	22.20	22.20
8	Tangent Galvanometer	4.50	36.00
2	Ammeter D.C. (if not in school)	13.80	27.60
1	6 or 12 volt car battery for large currents.	18.00	18.00
1	Magnetic forces apparatus	15.00	15.00
*8	Power Supply	59.00	472.00
*8	Rheostat	7.98	63.84
			$848.08

*Required only in schools where no provision is made for varying D.C. voltage.

APPENDIX B

IS P.S.S.C. SUITABLE FOR CANADIAN HIGH SCHOOLS?

APPENDIX C

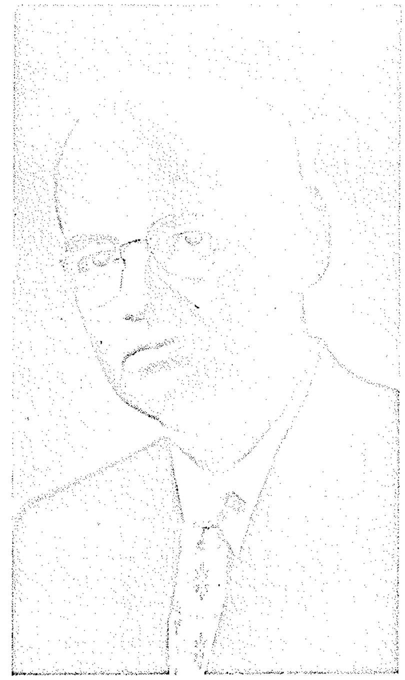
TESTS OF THE PHYSICAL SCIENCE STUDY COMMITTEE, SERIES O

NUMBERS 1, 3, 4, 5, 6 AND 7

s the P.S.S.C. Course Suitable 'or Canadian High Schools?

y Dr. John Hart

hairman, Department of Physics
arleton University, Ottawa



\n experiment with this new physics course at Carleton University iolds important implications for Canadian high schools. Says Dr. Hart: "I strongly advocate its wide adoption."

ABOUT three years ago, the secondary school physics course lesigned by the Physical Science Study Committee of the United States was introduced to Canadian high school teachers and physicists at carefully planned meetings and lemonstrations held across the ountry.

The P.S.S.C. course is a remarkable and possibly unique innovation n pedagogy. For this reason, its ntroduction is likely to be resisted by the more reactionary elements in our educational system. In my opinion, after a study of the course, t represents by far the best way of eaching high school physics that is available today, and I strongly advocate its wide adoption.

Later in this article I frankly discuss some of the limitations of the course. These criticisms are certainly not to be interpreted as indicative that the course is unsuitable for the Canadian educational system, and it is to be hoped that provinces who have been reluctant to co-operate in this daring experiment will feel moved to allow one or two schools to participate. As a matter of fact, some provinces have been teaching the course on an optional basis for two years, and there is sufficient information now for a more or less objective assessment of experience with the course. There has been much apathy and, worse, uniformed criticism about the course in Canada. And this article reviews the situation, admittedly on the basis of incomplete information.

Unfortunately, the promoters of the course have tended to emphasize the equipment and films that are integral with the textbook, rather than the far more important revolutionary philosophy and methodology. They are salesmen selling the sizzle, rather than the steak. This approach is a mistake as it has tended in the minds of administrators and inspectors to be equated solely with a request for more funds for laboratory experiments and audio-visual aids. Many of them may have missed the important message that the physicists had for the professional educators — that of discovery by doing. To quote the P.S.S.C. text: "When a student performs experiments, the results of which are not known in advance, he gains a feeling of participation in the discoveries of science". The method is not all that new: the text and teacher ask the questions and the pupil discovers the answers; Plato used it, but his student had appeal to reason rather than to experiment. The inductive method is applicable to many disciplines and is, incidentally, the basis of the better teaching machine programs. Secondary educators tend to be conservative, and the impetus for the development of a new teaching philosophy and the initiative in the revision of physics teaching has come from the universities, rather than the high school systems themselves.

Briefly, the course consists of a carefully integrated program of laboratory exercises and films controlled by the textbook. The philosophy of the course requires a flexible approach by the teachers. Those with exceptionally high initiative and experience are able to adapt their methods by reading the prefaces and teachers' instructional manuals, but most teachers need a few hours of "indoctrination" lectures to get them thinking along the right lines. Sympathetic inspectors and principals are a *sine quo non.*

In order to acquire first-hand experience of the course, we decided to teach it to the Qualifying Year at Carleton University; the results were presented to the Annual Meeting of the Canadian Association of Physicists as a basis for what turned out to be a lively discussion. As far as we know, the only other Canadian university to experiment with the course itself, apart from teacher training programs, is the Collège Militaire de St. Jean, and there it was abandoned after twelve weeks.

Current experimentation

This year, the course is being taught in many Canadian schools. Several provinces have experimented over the past two years in selected schools and are now ready to expand their experiment considerably. The four Western provinces are talking about a joint syllabus — a tremendous idea — and Saskatchewan has gone as far as to print an excellent optional P.S.S.C. syllabus. Ontario, New Brunswick, Newfoundland, Prince Edward Island have little or no experience with the course yet.

Departments of Education that have run the course are remarkably unanimous in their comments. In'tially, they have all selected achers for the course on the basis f interest and background; the elected teachers do not to date orm a valid sample of the teacher opulation. Those selected are sually sent to Princeton or a more ocal university for P.S.S.C. teacher raining courses. There is usually election of the best students, too. n effect, the P.S.S.C. course thus ecomes essentially a streamed and nriched program in physics. Re-action by selected teachers and tudents has been highly favour-able, except in the few places where eachers were unequal to their task ecause of insufficient training in ither physics or methodology. This exception is significant in erms of the more general adoption f the course.

The sense of achievement in the successful completion of quite complex experiments is a significant factor in its popularity with students. The text is criticized at all levels for being too wordy. Almost all students regard the course as challenging but difficult.

The preparation of teachers is paramount. The Quebec French-speaking system, which has diffi-culties with the course because of the lack of French language reference texts and films, is pre-pared to accept these limitations, but has no illusions about the teachers: "Le professeur non sufficiament préparé tombe in-faillibliment dans son aucien méthode et l'experiènce qu'on voulait faire devient absolument nulle". Teachers have real difficulty in throwing off the old method of learning by rote and problem-solving by formula. (Not that the universities are by any means blameless in this respect.)

However, Saskatchewan finds that most physics teachers can and do become enthusiastic about the course if they have been oriented by six-weeks' training in the summer. The average student gets more intellectual challenge out of this program than he does from the traditional course, though his marks are lower. (I discuss the problem of examinations later in this article.) It is perhaps signifi-cant that, in Saskatchewan, both the university science departments and the Teachers' Federation play a prominent part in the develop-ment of science.

Carleton's experience

Having now set the stage, perhaps I can discuss our own limited experiences at Carleton. The Qualifying Physics Year at Carleton University consists of about 90 students who entered with high standing (a nominal, un-enforced minimum average of 70 per cent) in the Ontario Junior Matriculation examinations, or with equivalent standing from similar examinations in other provinces. If these students had not entered the Qualifying Year, they would have taken the ordinary grade 13 senior matriculation academic course in an Ontario high school, entering the university one year later. The course is not regarded in the Physics Department as being a part of the university work proper and, with the exception of scholarship winners, we prefer to have students stay in high school till the end of grade 13. We deliberately chose a mature graduate student as in-structor; he has a Master's degree in physics and will probably, within a few years, enter university teaching. His teaching manner and methodology were good, but apart from one year's demonstrating duty in an elementary laboratory, he had no substantial teaching experience.

Basic mistakes made

We can say unequivocally that *we failed the P.S.S.C. course* right from the start (not *vice versa*). The failure occurred when we con-sidered using the course *in toto*. We made a rough calculation of the teaching hours that would be expended if we followed the "self-teaching" method advocated, and found them to be excessively large. Conditions in university elementary classes are somewhat different from those pertaining in high schools. The supervision of the rather free-running laboratories, carried out by part-time demonstrators and in-experienced graduate students, posed insuperable problems. We also had some criticism of the laboratory experiments, which we shall discuss later. We judged that the text material was inadequate to provide a basis for our first-year physics course, and we used supple-mentary texts. In other words, our course was emasculated, but inflated! We should state that, despite this limitation, the P.S.S.C. course, properly assimilated, would in our opinion unquestionably make a better foundation for university work than the present Ontario grade 11 and grade 13 syllabus (no physics is taught in grade 12).

Because of the varied mathe-matical backgrounds of the students, a review of algebra and an introduction to trigonometry were more or less mandatory. (The interaction of the course with the mathematics syllabus is mentioned by some Departments of Educa-tion.) The trigonometry proved a necessary tool in Part I of the text, "The Universe". We found it con-venient and even necessary to skip Part II, "Optics and Waves", until we had completed a chapter on electromagnetic waves farther on in Part IV. We excluded material on geometrical optics, which is not well done anyway, and concentrated on the more basic physical optics. So, Part III of the text, "Mechanics", was given after Part I. This section was extended to cover a larger area of rotational dynamics; the chapter on heat was also extended. The course deals well with the limitations of the wave theory of light, and it attempts to prepare the students for the necessarily low-level study of photons, de Broglie waves, quantum systems and the structure of atoms. But we felt it necessary to elaborate on many points, such as black body radiation, to make the discussion really fruitful. Part I and Part III occupied the full first term from September to Christmas, Part IV and Part II occupied the second term from January till May. An examination set by the Physics Department was given after each major portion of the text was completed.

Students' evaluation

In an attempt to obtain the re-actions of our students, we asked them to complete questionnaires anonymously; the questions were divided into three parts relating to the textbooks, the films and the experiments. There were many individual remarks on the question-naire returns, some of them of relevance; I will attempt to summarize opinions, theirs and ours combined.

The textbook is good but wordy,

...it has clearly been written by a ...mmittee! The students spotted ...is defect and were consequently ...spicious of even some of the ...tter chapters. The order of ...esentation, as we have already ...iplied, leaves something to be ...sired. Some of the points made ... the text are too subtle for ...udents at this level to appreciate. ...iite a few chapters contain ...eful summaries that mitigate the ...ult of wordiness, but a brief ...ithoritative and adequate statement of definition of terms is often ...osent. Even at a much higher ...vel, this fault can cause endless ...ouble. It may perhaps be argued ...iat no definition can ever be complete, and it is therefore better to ...ave out definitions altogether. ...his argument is of doubtful ...ilidity for even the brightest ...udent, and lack of definition has ...used polemics at the highest ...vels of theoretical research. ...ertainly, at this level, good definitions are vital to understanding. ...n the whole, we found the book ...anting in too many respects to ...erve *our* needs as a Qualifying ...ear text.

We have a selection of apparatus ...ecommended for use with the ...ourse, but our long and disheartening experience with Qualifying Year students led us to use our ...wn more rugged experiments; ...ome of the P.S.S.C. experiments ...re well conceived but are poorly ...nade to the point of trashiness. At ...he age of 17 or 18, the students ...end to evaluate these at their face ...value; at a *much* earlier age, the simpler experiments would be exciting, and they should be given to high school students at the age of 15 or so. A lesser criticism of some of the more sophisticated experiments is that they are ingenious but artificial, and give a mistaken idea of the way in which physicists go about their work.

THE P.S.S.C. COURSE "IN A NUTSHELL"

The Physical Science Study Committee is a group of American and Canadian teachers and professors devoted to the development of improved physics courses. In the textbook, which the Committee has produced, physics is presented as an exciting, continuous, and open-ended subject. Visual aids, demonstrations, laboratory experiments, and examinations are carefully integrated with the text in an unusual and novel manner. The course which has evolved from the studies of the Committee is designed to be intellectually stimulating to the students, and eschews learning by rote.

The material covered includes elementary mechanics, waves, electricity, optics and atomic structure—all rigorously treated without the use of calculus, though some simple trigonometry is naturally required. The laboratory experiments require the use of reasonably elementary apparatus that should be within the budget of most high schools, and range from the measurement of time and distance to particle collisions and radioactive decay.

It is not easy to assess the level of the course in terms of the Canadian system. It presupposes no knowledge of physics, and takes a student to about the level of grade 13 (Senior Matriculation) in Ontario. Because of its unusual methodology, it cannot be compared directly with any other Canadian course.

The author of the laboratory guide tells the students that it "leaves the thinking to you". That, in a nutshell, is the P.S.S.C. course.—Dr. John Hart.

Film quality variable

Like the textbook, the films are variable in quality. Some of the better-known ones, like "Frames of Reference" and "The Millikan Oil Drop", are really first class; some of them are mediocre, and in one particular film (which it would be uncharitable to name), the mannerisms of the lecturer kept the class in a state of uproar for some 30 minutes. That film just should not have been included. A criticism of the more elaborate film demonstrations is that the amount of apparatus used is excessive and it is difficult for the student to sort out the desired information. In some films, the criticism already made of the laboratory experiments applies, and the professor appears to have been blinded by his own ingenuity. In others, such as the one mentioned above depicting the more or less quantitative oil drop experiment, useful quantitative information which could be readily made available is not supplied. Some well-qualified physicists are of the opinion that some of the experiments are cooked; we do not think that this is so, but we think it unfortunate that they give some people the *impression* of being cooked, which is just as bad from a pedagogical point of view. One point to remember about these films is the unfortunate habit that they have of referring specifically to another film, which forces one to show the films in order; the brochure describing the films does not mention this fact. It was found necessary to extend the classroom time because of the time consumed by the films, and this was done by reducing the number of laboratory periods.

We did not use the P.S.S.C. examinations. Our questions were not what is commonly called objective, and some essays were called for. If you are interested in our pass rate, the final results in the class of 91 were 51 passed and 40 failed, which is about normal for our Qualifying Year course. But this would be unacceptable in a high school.

To summarize, we conclude that the course could, and indeed should, be taught to students well before entering grade 12 in Ontario high schools or its equivalent. Our experience indicates that the course could well start at the grade 10 level at age 14 or 15. The ramifications of such a policy would be manifold.

Suitable for general use

Opinion regarding teachers and students is not uniform. Some authorities have the opinion that the P.S.S.C. course is to be taught only by teachers who are intellectually energetic to the more intelligent students, and that it is ot suitable for general use. If this is so, it raises the whole problem of streaming. If the course is to be taught at all, it must be assumed that the most receptive students have been pre-selected. Many provinces do in fact stream their secondary school students, and with the increased demand for full intellectual development, particularly in scientific and technical disciplines, this practice will be extended. If the P.S.S.C. course is taught, an alternative has to be available. Some provinces state quite categorically that they cannot adopt the course in a non-streamed publicly supported school system. Other provinces have found that the course can be used in most physics classes and that there is no streaming problem at all.

Difficult to assess results

One of the greatest difficulties associated with the course is the assessment of performance. It seems that the examinations conducted using P.S.S.C. questions result in a very wide range of marks, from just about zero to just about 100 per cent which, considering that the students were pre-selected and in some cases definitely of scholarship standard, leaves the authorities in an awful quandary over the school leaving certificates. One would like to guess that the P.S.S.C. examination results are a measure of intellectual activity and provide a better criterion of university performance than the present provincial examinations, but such a conclusion is not justified. In the meantime, the students who have been awarded poor marks on the basis of the P.S.S.C. examinations have some justification for saying "We was robbed". Many provinces supplement the examinations with their own questions. University professors who serve on provincial examination boards are well aware of the difficulties involved in setting and marking "think" type questions in all disciplines, and they have heard the outcry that arises if such a question gets through the screening committee on to the examination paper. Perhaps the P.S.S.C. course is the thin end of the wedge, not only in promoting a change in methodology, but in examination procedures, too.

The length of the course is such that the authorities are virtually unanimous in recommending Canadian programs taken over two academic years. In Ontario, this would have the beneficial effect of re-introducing physics into the grade 12 syllabus, from which it is at present mysteriously absent. When taught over a one year period, the course appears to have had a detrimental effect on other parts of the curriculum, and one can well imagine the tensions that result in both the teaching staff and the students, not to mention the poor principal! In the United States and Great Britain (where the course is under active consideration), education is more limited in diversity in any one year, and a period of one academic year might be sufficient.

The cost of the course, though it has been kept minimal by such tricks as the use of everyday household fittings in the laboratory, is high in terms of the traditional Canadian expenditures on secondary school science. Even though the experimental apparatus is simple and cheap, many high schools, particularly those controlled by local boards, may have difficulty in prying money loose. Insistence on the experimental approach at an early age has been reiterated time after time by Canadian physicists, and local collegiate boards must provide facilities for individual experimentation at all levels, whether or not the P.S.S.C. course is adopted. The more advanced levels of any physics course definitely require adequate laboratory facilities.

Comments from Canadian physicists

The discussion from the floor at the meeting of the Canadian Association of Physicists mostly covered the points that I have already mentioned. "Objective" examinations came under fire, and the necessity for practice in writing essay-type answers was stressed; it is ironic that a course that has such a wordy textbook calls for a staccato examination. We all know how difficult is the art of scientific writing, and particularly how painful is the process of putting words, numbers, and diagrams into one cohesive article; the preparation of good laboratory reports may provide some practice in this necessary skill. But it takes time to write, and we run against the barriers of full curricula and inadequate staffs. A teacher teaching physics courses properly needs some 50 per cent spare time for preparation and marking. In terms of economics, this means a doubling of the salary bill, if the teachers were available, which they are not.

Is there any serious conclusion to be drawn at this stage? Perhaps not. Physicists in the United States are apparently satisfied with the course to the extent that they are now turning to a similar project in the field of college physics. Great Britain, which already has a special scholarship school-leaving examination composed of "think" questions, is interested, and has a full-time committee working on a P.S.S.C. type course. The chemists and biologists are also investigating the "new methodology".

Implications of the P.S.S.C.

My own impression is that the P.S.S.C. course is important, not so much for what it is doing for physics teaching, but for what it is likely to do for many aspects of pedagogy. It will, as its adoption becomes more general, lead to a change of thinking on streaming, timetabling, curriculum, and (dare we say?) financing. The problems to be solved in the teaching of physics are enormous. How can a course that requires more and better teachers than ever be successful in a society that already demands too much of its teachers, and sees replacements coming along too slowly to keep up the present strength? Put the problem in terms of national development, and it is quite clear that we should back brains with our cash, and invest our money in the people that are going to lead the scientific and technological developments that our economy needs.

Here we have a clear question to be answered: are we prepared to make the changes in our educational systems that the times call for? The physicists say that we must do so. Physics is, by definition, the primary scientific discipline, and it is no coincidence that the physicists are turning out to be the educational radicals of the decade. ■

Test 1
Part 1
Chapters 1-6

TESTS OF THE

PHYSICAL SCIENCE STUDY COMMITTEE

TEST 1: Space, Time, and Motion

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

A Mass
B Time
C Length
D Density
E Force

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO

Published by Cooperative Test Division, Educational Testing Service, Princeton, N. J. • Berkeley 4, Calif.

Questions **1-4** relate to the following information:

A bus makes a trip from Boston to Washington via New York and Philadelphia. The following table shows times and distances for various parts of this trip. In each case the number of figures indicates the accuracy to which the measurements were taken.

	Time	**Distance**
Boston to New York	6.0 hours	248.2 miles
New York to Phila.	2.29 hours	102 miles
Phila. to Washington	4.891 hours	142.73 miles

1 The total time for the trip is properly expressed as

A 13 hr.
B 13.1 hr.
C 13.2 hr.
D 13.18 hr.
E 13.181 hr.

2 The total distance traveled by the bus is properly expressed as

A 490 mi.
B 492 mi.
C 493 mi.
D 492.9 mi.
E 492.93 mi.

3 The average speed of the bus between Boston and New York is properly expressed as

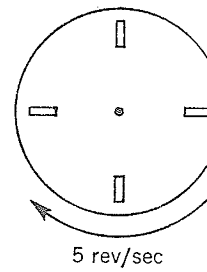
A 41.366 mi/hr
B 41.37 mi/hr
C 40 mi/hr
D 41 mi/hr
E 41.3 mi/hr

4 The average speed of the bus between Philadelphia and Washington is properly expressed as

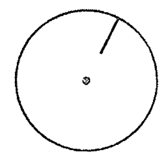
A 29.184 mi/hr
B 29.18 mi/hr
C 29.2 mi/hr
D 29.0 mi/hr
E 29 mi/hr

Questions **5-7** relate to the following informatic and diagram:

A certain stroboscope consists of a rotating disk wi four slotted holes, as shown below. The disk is rota ing at exactly five revolutions per second.



5 The stroboscope "stops" the motion of a whee making it appear as in the diagram below:



The rate of rotation of the wheel is at LEAS

A 1.25 rev/sec
B 5.00 rev/sec
C 20.0 rev/sec
D 25.0 rev/sec
E 80.0 rev/sec

6 The stroboscope is used to take a single photograph showing pictures at several positions o a ball rolling along a level surface at a constan velocity of 4 meters per second. How far wil the ball have moved between successive positions?

A 0.2 meters
B 0.8 meters
C 1 meter
D 5 meters
E 8×10 meters

7 If the stroboscope had speeded up while the photograph was made, without the experimenter knowing that the speed had changed, the

A pictures would have become blurred.
B ball would appear to have slowed down.
C ball would appear brighter in successive pictures.
D photograph would be unchanged.
E successive pictures of the ball would be farther apart.

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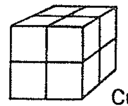
uestions **8-11** relate to the following information and diagram:

onsider several cubical structures made up of identical cubical building blocks. The simplest, made of a single ock, is called cube #1. Cube #2 contains eight blocks and has two blocks along each edge. Cube #3 has three, ıd cube #4 has four blocks along each edge. Cube #N has n blocks along each edge. Every edge of a building lock has a length x.



Cube #2

8 The number of unit cubes in cube #N is

A n^3
B $3n$
C 3^n
D 3^{n+1}
E 3^{n-1}

9 The total area of the outside surfaces of cube #N is

A $6xn^3$
B $6x^2n$
C $6x^2n^2$
D $6x^2n^3$
E some other value

10 The volume of cube #N is

A xn^3
B x^3n
C x^3n^3
D $3x^3n$
E some other value

11 To get the volume of cube #N, the volume of a single building block must be multiplied by

A n
B n^2
C n^3
D $3n$
E $6n$

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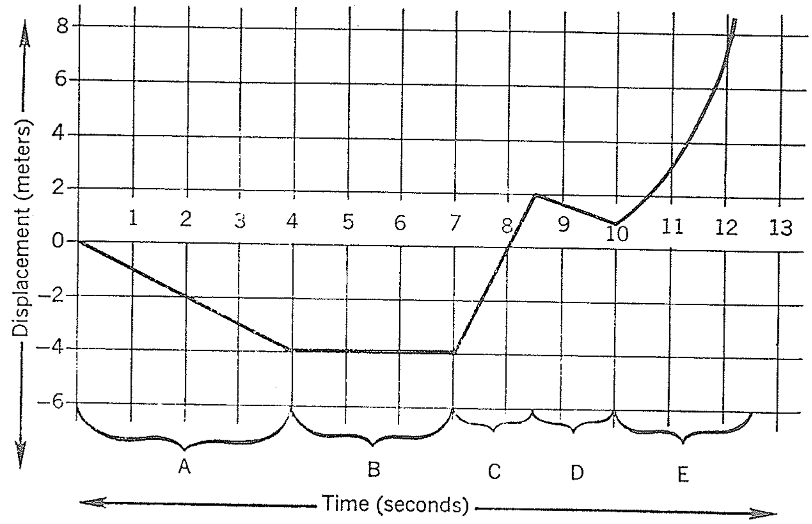
Questions **12-17** relate to the following information and graph:

An object is moving along a straight line. The graph shows its displacement from the starting point as a fun tion of time. Various sections of the graph are identified by the letters *A*, *B*, *C*, *D*, and *E*.



12 The displacement of the object at the end of the first seven seconds is

A 4 meters
B –4 meters
C $\frac{4}{7}$ meters
D $\frac{7}{4}$ meters
E $\sqrt{65}$ meters

13 Which section of the graph represents a constant velocity of +4 meters per second?

A *A*
B *B*
C *C*
D *D*
E *E*

14 Which section of the graph represents a time during which the object was at rest?

A *A*
B *B*
C *C*
D *D*
E *E*

15 What was the *average velocity* of the objec during the first six seconds?

A 4 meters/sec
B – $\frac{4}{6}$ meters/sec
C 0 meters/sec
D $\frac{6}{4}$ meters/sec
E $\frac{4}{6}$ meters/sec

16 Which section of the graph represents a perio of positive acceleration?

A *A*
B *B*
C *C*
D *D*
E *E*

17 What was the *instantaneous velocity* of th object at the end of the fifth second?

A 4 meters/sec
B 2 meters/sec
C $\frac{4}{6}$ meters/sec
D 0 meters/sec
E – $\frac{4}{6}$ meters/sec

uestions **18-22** relate to the following information:

'wo airports, I and II, are 600 kilometers apart; II is directly east of I. A plane which maintains a constant peed of 400 kilometers per hour, relative to the air, leaves Airport I at 9 a.m. A steady wind is blowing *from* he north, its speed relative to the ground being 100 kilometers per hour.

8 During the trip along a straight line path from Airport I to Airport II, the pilot must keep the nose of the plane pointed

A exactly to the east.
B between east and 30° north of east.
C between east and 30° south of east.
D more than 30° north of east.
E more than 30° south of east.

19 During the flight, the speed of the plane relative to the ground will be approximately

A 300 km/hr **C** 400 km/hr
B 390 km/hr **D** 410 km/hr
E 500 km/hr

20 A second plane leaves Airport II at the same time that the first leaves Airport I, and flies in a straight line to Airport I. Its speed relative to the ground is 300 kilometers per hour. Its speed relative to the air is approximately

A 200 km/hr **C** 300 km/hr
B 280 km/hr **D** 320 km/hr
E 400 km/hr

21 During the flight, the speed of the first plane relative to the second is approximately

A 600 km/hr **C** 700 km/hr
B 690 km/hr **D** 710 km/hr
E 800 km/hr

22 The planes can be expected to pass each other

A less than $\frac{1}{4}$ of the way from I to II
B between $\frac{1}{4}$ and $\frac{1}{2}$ of the way from I to II
C exactly halfway between I and II
D between $\frac{1}{2}$ and $\frac{3}{4}$ of the way from I to II
E more than $\frac{3}{4}$ of the way from I to II

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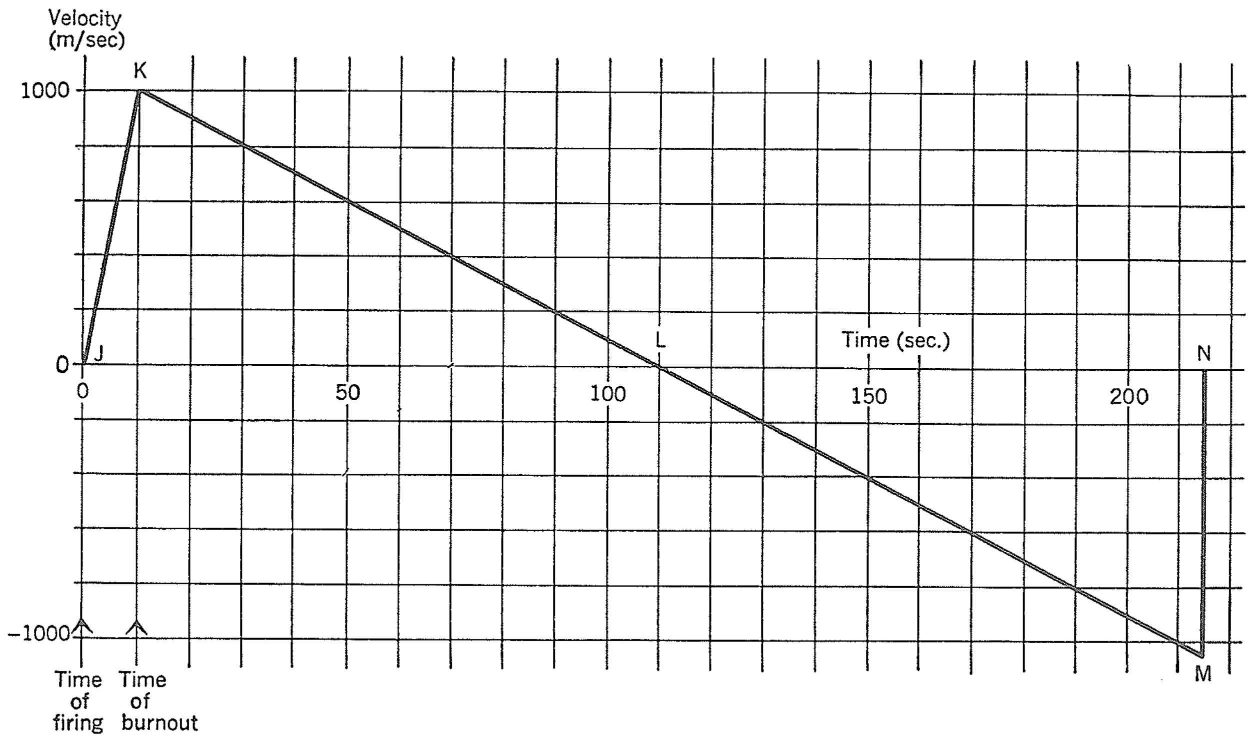
Questions **23-27** relate to the following information and graph:

The graph shown below represents approximately the velocity of a small, single-stage rocket, which was fire[d] vertically and which has negligible air resistance.



23 The area of the figure *JKL* is exactly equal to the area of the triangle *NML* because

A the rocket rises and falls with the same acceleration.
B the speed with which the rocket strikes the earth on its return is equal to its greatest speed.
C the rocket is at rest at the top of its flight.
D the distance that the rocket rises is equal to the distance through which it falls.
E particular values of time and velocity were chosen for this problem to insure this equality.

24 The acceleration during the burning of the rocket is approximately

A 100 meters/sec^2 **C** 400 meters/sec^2
B 200 meters/sec^2 **D** 1000 meters/sec^2
E none of the above

25 The height at which the rocket engine burns out is approximately

A 200 meters **C** 1000 meters
B 500 meters **D** 5000 meters
E 10,000 meters

26 The rocket reaches its maximum height at time

A 5 sec. **C** 110 sec.
B 10 sec. **D** 215 sec.
E none of the above

27 The maximum height reached by the rocket is approximately

A 1.0×10^3 meters **C** 10×10^3 meters
B 5.0×10^3 meters **D** 50×10^3 meters
E 55×10^3 meters

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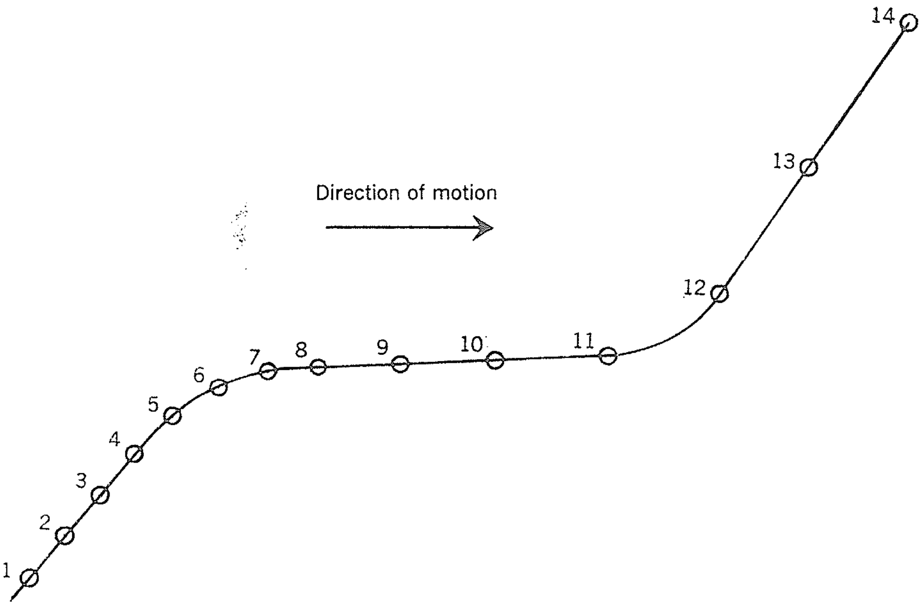
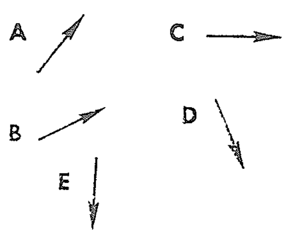
Questions **28-31** relate to the following photograph and information:

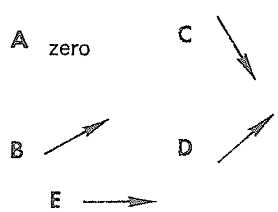


The figure shows a stroboscopic photograph of a ball that moves along the path . . . . 1, 2, ... , 13, 14. . . . . The regions 1-4, 8-11 and 12-14, are straight lines; the regions 4-8 and 11-12 are circular arcs. The time intervals between successive positions of the ball are all equal.

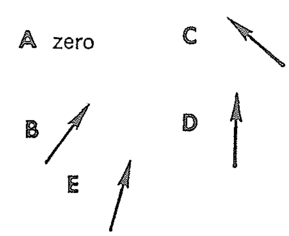
28 The instantaneous velocity of the ball at point 6 is best represented by which of the following?



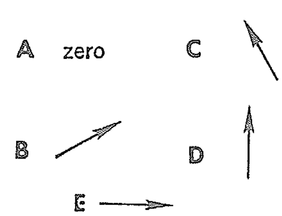
29 The instantaneous acceleration of the ball at point 6 is best represented as



30 The instantaneous acceleration of the ball at point 13 is best represented by



31 The instantaneous acceleration of the ball at a point halfway between positions 11 and 12 is best represented as



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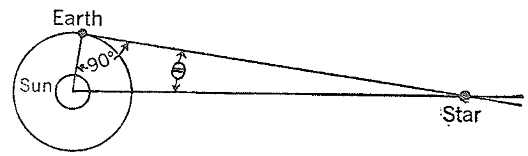
Questions **32-35** relate to the following information and diagram:

Definitions:

1 The stellar parallax of a star is defined as the angle between two lines, one from the star to the sun and tl other drawn from the star tangent to the earth's orbit. It is the angle θ in the diagram below.

2 A parsec is a unit of distance, defined as the distance from the earth of a star whose stellar parallax is exact one second of arc.



Situation:

The light reaching the earth from three identical stars has been observed and it has been found that:

Star I shows a parallax of 0.5 second of arc

The intensity of light from Star II is one-fourth the intensity of light from Star I

Star III shows a parallax of 1.0 second of arc

32 All of the following statements about Star I are true EXCEPT

A it is closer to the earth than is Star II
B it is farther from the earth than is Star III
C it is closer to the earth than is Star III
D the intensity of its light is less than that from Star III
E its stellar parallax is greater than that of Star II

33 The distance of Star I from the earth is

A 0.5 parsecs
B 1.0 parsecs
C 2.0 parsecs
D 30 parsecs
E none of the above

34 The ratio of the distance of Star II to that c Star I is

A 4:1
B 1:4
C 2:1
D 1:2
E not determinable from the data give

35 Which one of the following combinations list the three stars from brightest to faintest a seen from the earth?

A Star III, Star I, Star II
B Star I, Star II, Star III
C Star III, Star II, Star I
D Star I, Star III, Star II
E Star II, Star III, Star I

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Test 3
Part 2
Chapters 11-15

TESTS OF THE PHYSICAL SCIENCE STUDY COMMITTEE

TEST 3: The Behavior of Light

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

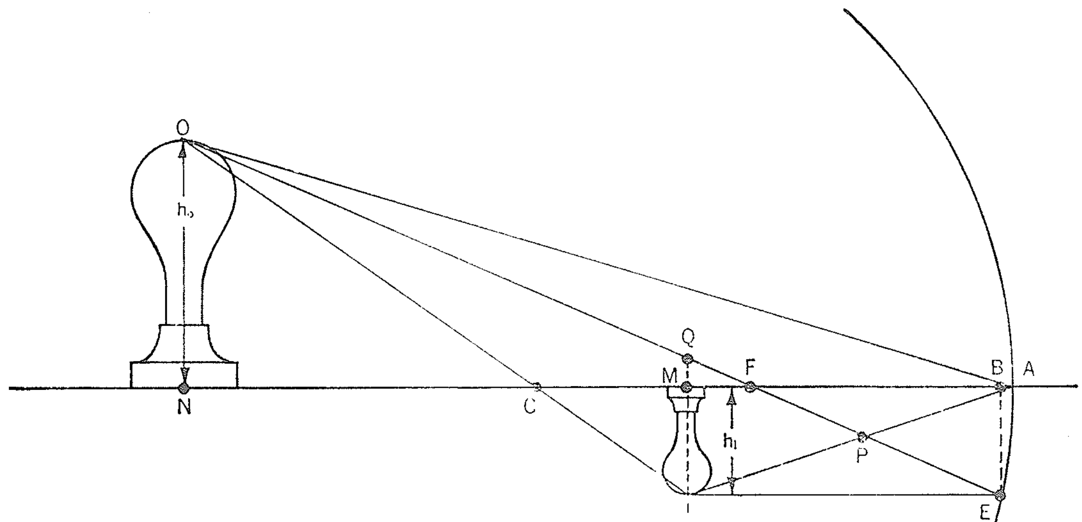
A Mass
B Time
C Length
D Density
E Force

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO

Published by Cooperative Test Division, Educational Testing Service, Princeton, N. J. • Berkeley 4, Calif.

Questions **1-4** relate to the following information and diagram:

A light bulb and its image are shown together with a concave mirror. A number of pairs of similar triangles occur in the diagram.



A The similarity of triangles *CNO* and *CMI*
B The similarity of triangles *FNO* and *FBE*
C The similarity of triangles *ANO* and *AMI*
D The close similarity of triangles *PQI* and *PAE*
E None of the above

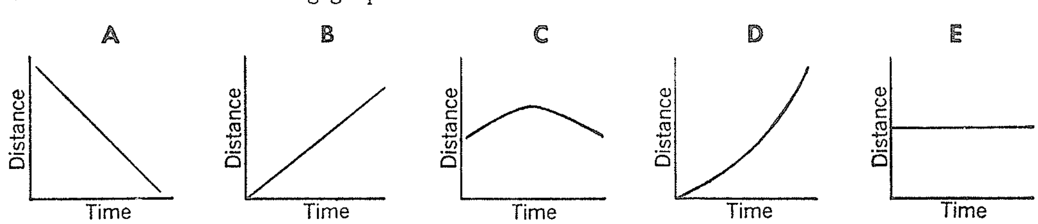
1 From which of the above relations of similarity can one conclude that the ratio of object height to image height is approximately the same as the ratio of object distance from *F* to the focal length of the mirror?

2 From which of the above relations of similarity can one conclude that the ratio of object height to image is the same as the ratio of object distance from *C* to image distance from *C*?

3 From which of the above relations of similarity can one conclude that the ratio of object height to image height is the same as the ratio of object distance from *A* to image distance from *A*?

4 From which of the above relations of similarity can one conclude that the ratio of object height to image height is approximately determined by the focal length of the mirror alone?

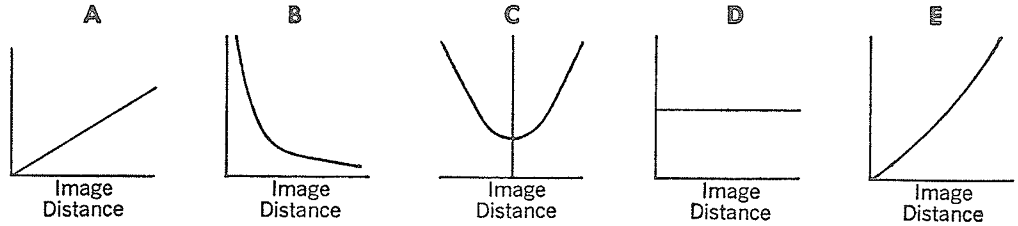
Questions **5-6** relate to the following graphs:



5 As a man walks away from a plane mirror at a uniform velocity, which graph most nearly represents the distance of his image from him with respect to time?

6 As a man walks toward a plane mirror at a uniform velocity, which graph most nearly represents the distance of his image from him with respect to time?

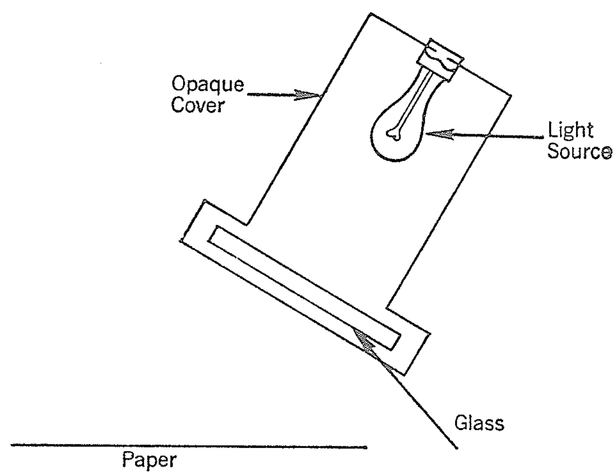
Questions 7-8 relate to the following graphs:



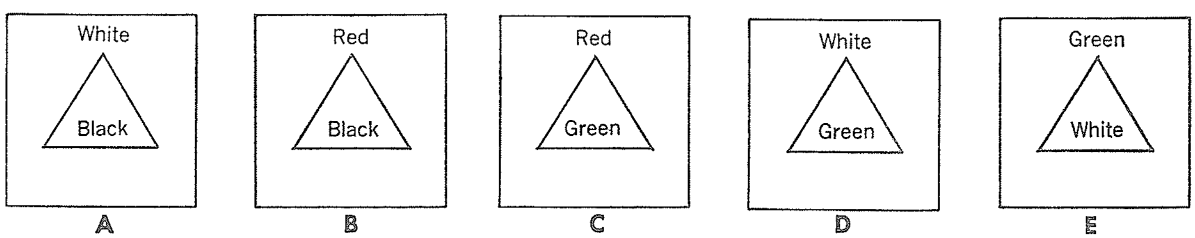
7 Which graph might represent object distance as a function of image distance in the case of a concave mirror? (Both distances are measured from the principal focus, and both the image and object are farther from the mirror than the focal length.)

8 Which graph might represent image area as a function of image distance in the case of a converging lens? (The image distance is measured from the second principal focus.)

Questions 9-11 relate to the following diagram and information:



A source of white light, arranged as shown in the diagram, is used to illuminate any one of several pieces of paper, each of which has a triangle painted on it. The various pieces of paper, as they appear in white light, are represented below. Either of two pieces of glass, one green and one red, may be placed between the light source and the paper, so that the only light reaching the paper is that transmitted by the glass.



Choose the piece of paper that will have the appearance described in each statement below.

9 The green glass is used and the triangle is seen clearly as being much darker than the rest of the paper.

10 The red glass is used and the triangle is seen clearly as being much lighter than the rest of the paper.

11 The green glass is used and the triangle can hardly be distinguished from the rest of the paper, the entire paper appearing dark.

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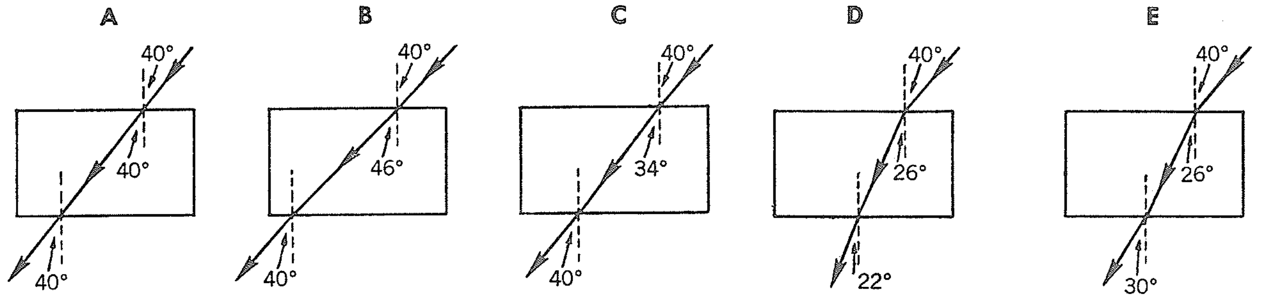
Questions **12-16** relate to the following information and diagrams:

A block of clear glass, with opposite faces parallel, is placed successively in various transparent, colorless liquids referred to as liquid 1, liquid 2, and liquid 3. The table on the right gives the refractive indices of the optical media involved:

Air	1.0
Liquid 1	1.3
Liquid 2	1.5
Liquid 3	1.7
Glass	1.5



For each of the situations given below, select the diagram which best represents the path of a ray of light passing through the glass under the conditions described.

12 The block of glass is entirely submerged in liquid 1.

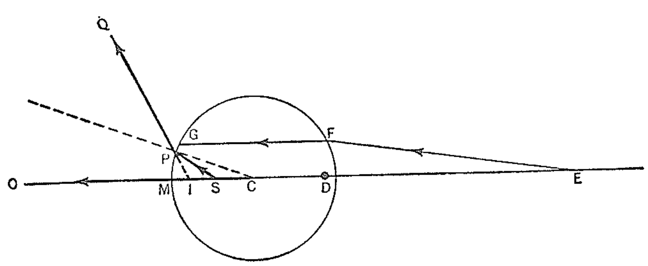
13 The block of glass is entirely submerged in liquid 2.

14 The block of glass is entirely submerged in liquid 3.

15 The block of glass is placed in liquid 1 in such a way that only its lower half is submerged.

16 The block of glass is placed in liquid 3 in such a way that only its lower half is submerged.

Questions **17-19** relate to the following diagram and information:



A thin-walled glass container, in the shape of a sphere, is completely filled with water and sealed. The wall is so thin that the optical effect of the glass may be neglected and the system considered to be a sphere of water. The sphere is used as a crude lens, to produce an image of a point source of light. For example, with the source at *S*, two rays starting from it are refracted in the directions *MO* and *PQ*, so that the image is at *I*. For each of the other source locations described below, select the heading which best describes the location of the image as seen by an observer located to the left of the sphere.

A The image is at the center, *C*, of the sphere.
B The image is within the sphere, to the left of *C*.
C The image is within the sphere, to the right of *C*.
D The image is outside and to the left of the sphere.
E The image is outside and to the right of the sphere.

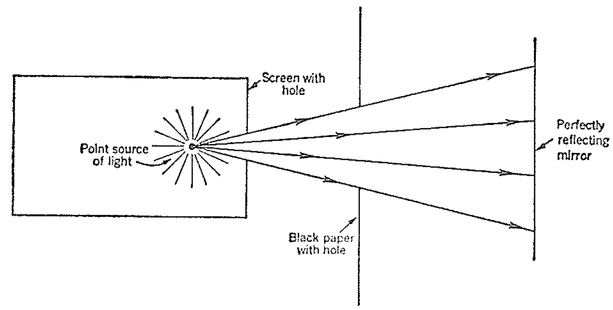
17 The source is at *C*, the center of the sphere.

18 The source is at *D*, just inside the sphere.

19 The source is at *E*, so located that the ray *FG*, inside the sphere, is parallel to the axis *ECO*.

Questions **20-24** relate to the following information and diagram:

A diverging beam of light is produced by limiting the light coming from a point source by the use of a fixed screen with a circular hole in it. The beam then passes through a circular hole in a piece of *perfectly absorbing* black paper as shown. It then falls on a *perfectly reflecting* plane mirror placed parallel to the black paper as shown in the diagram.



20 One can correctly predict that the light coming through the hole in the screen will be

A eventually completely absorbed by the black paper.
B partially absorbed by the mirror and partially absorbed by the black paper.
C partially absorbed by the paper and partially returned through the hole.
D entirely returned through the hole.
E partially absorbed by the mirror, partially absorbed by the black paper, and partially returned through the hole.

21 According to the particle theory of light, one would expect that the

A mirror and paper would both be pushed to the right.
B mirror and paper would both be pushed to the left.
C mirror would be pushed to the right and the paper to the left.
D mirror would be pushed to the left and the paper to the right.
E pushes on the mirror and paper would just balance so that neither receives a push.

22 Under which one of the following changed conditions would the intensity of the light *reflected* onto the black paper be increased?

A The black paper alone is moved toward the point source.
B The mirror alone is moved away from the point source.
C The point source, together with the box containing it, is moved away from the hole in the black paper.
D The diameter of the hole in the black paper is increased.
E The distances of both the mirror and black paper from the source are made half as great at the same time the intensity of the source is reduced by half.

23 According to the particle theory of light, the pressure produced by the light reflected onto the black paper will be twice as great as that on the mirror

A under all conditions.
B under no conditions.
C if the distance from the mirror to the black paper is one-half the distance from the source to the black paper.
D if the distance from the mirror to the black paper is $(\sqrt{2} - 1)$ times the distance from the source to the black paper.
E if the distance from the mirror to the black paper is one-fourth the distance from the source to the black paper.

24 Which one of the following predictions is in complete accord with the particle theory of light?

A The mirror alone will be heated by the light.
B The black paper alone will be heated by the light.
C Neither the black paper nor the mirror will be heated by the light.
D Both the mirror and the black paper will be heated by the light, the paper being heated a little more than the mirror.
E Both the black paper and the mirror will be heated by the light, the mirror being heated a little more than the paper.

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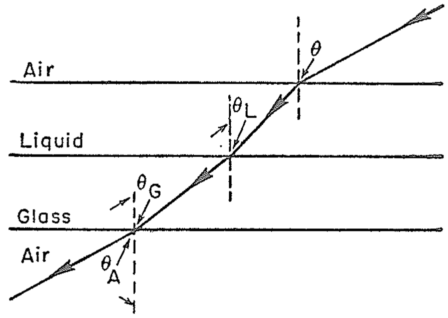
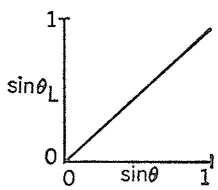
Questions **25-28** relate to the following diagram and information:



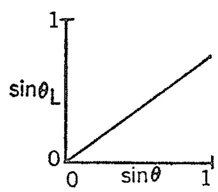
A narrow pencil of light falls on the horizontal surface of a liquid in a glass tank at the angle of incidence θ as shown in the diagram. The index of refraction of light passing from air to the liquid is n_L and that for light passing from air to glass is n_G.

25 As θ is changed from 0° to 90°, the graph which best represents the way in which $\sin \theta_L$ changes is

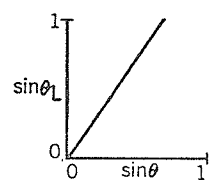
A



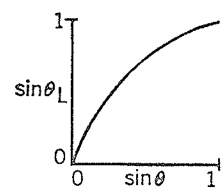
B



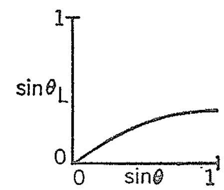
C



D

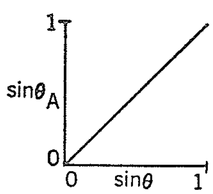


E

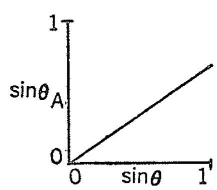


26 As θ is changed from 0° to 90°, the graph which best represents the way in which $\sin \theta_A$ changes is

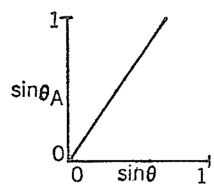
A



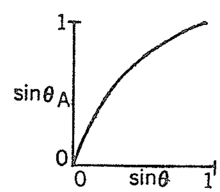
B



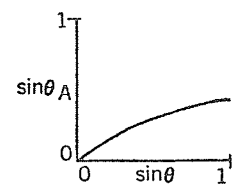
C



D



E



27 If the path of the transmitted light is as shown in the diagram for $\theta = 60°$, all of the following conclusions are certain EXCEPT:

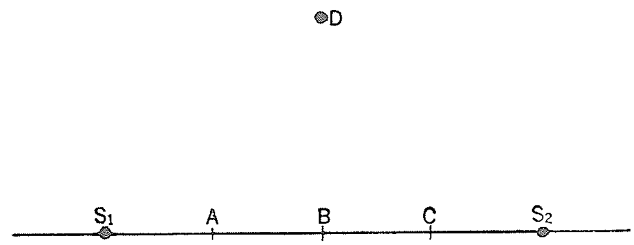
A n_L is greater than unity.
B n_G is greater than unity.
C n_G is greater than n_L.
D Light would travel along the same path in the opposite direction.
E Some reflection of light takes place at each boundary between two media.

28 Total internal reflection of light that enters the liquid from the air above will take place at the boundary between the bottom of the glass and the air

A only when $\dfrac{\sin \theta_G}{\sin \theta} = n_G$
B whenever $\dfrac{\sin \theta_G}{\sin \theta}$ is greater than n_G
C whenever $\dfrac{\sin \theta_G}{\sin \theta}$ is less than n_G
D for all values of θ
E for no possible value of θ

GO ON TO THE NEXT PAGE

Questions **29-32** relate to the following diagram and information:



Two point sources of light, S_1 and S_2, can be turned on and off at will and are located as shown in the diagram above. The distances S_1A, AB, BC, and CS_2 are all equal. Point D is directly above point B, and DB is equal in length to S_1B. The strength of source S_2 is twice that of S_1. With only S_1 on, the light intensity at B is found to be 4 units.

29 With only S_1 on, the light intensity at A compared to that at C is

A 1
B 1/4
C 4
D 1/9
E none of the above

30 If S_2 is turned on and S_1 is turned off, the intensity at B will be

A 2 units
B 4 units
C 8 units
D 16 units
E none of the above

31 Suppose that a piece of opaque paper is placed at B, perpendicular to the line $S_1 - S_2$. With both S_1 and S_2 on, the ratio of the intensity on the *left* side of the paper to that on the *right* side is

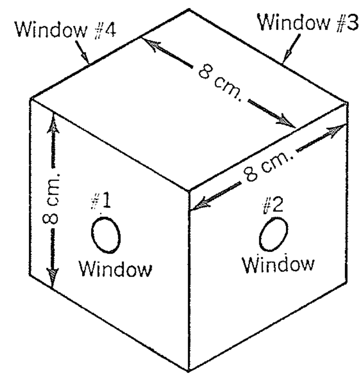
A 1:4
B 1:2
C 1:1
D 2:1
E 4:1

32 Suppose that the light source S_1 is moved to D and that S_2 is turned off. The intensity at A will then be closest to

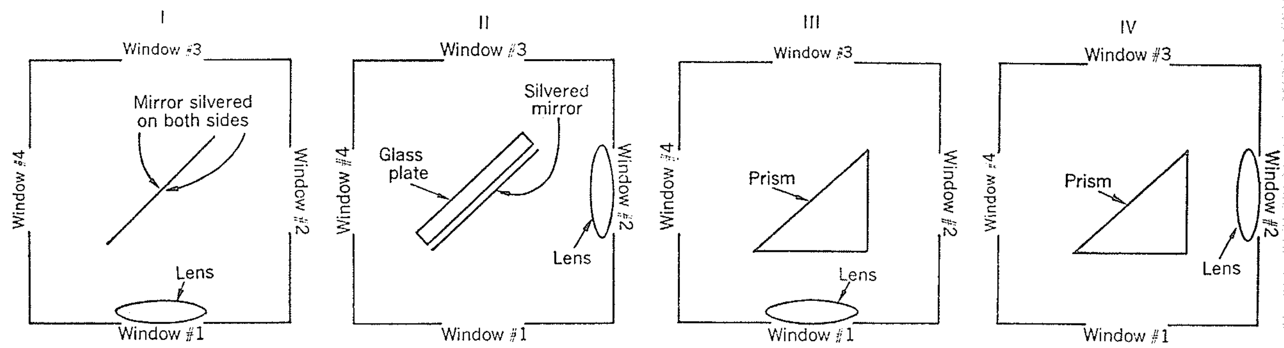
A 2 units
B 3 units
C 4 units
D 5 units
E 6 units

GO ON TO THE NEXT PAGE

Questions **33-35** relate to the following diagrams and information:



A cubical box, 8 cm. on each edge, has four small windows, one on each vertical side, as shown in the diagram above. The windows are numbered #1, #2, #3, and #4. An observer notices that when he looks into window #4, he sees a virtual image of an object that is outside the box, near window #3. He suggests several possible "models" of the box to explain these observations. The diagrams below show these models.



33 Which of the models will satisfactorily explain his observation?

A I and II only **C** I and III only
B III and IV only **D** II and IV only
E I, II, III, and IV

34 The observer places an object 5.0 cm. outside window #2. When he holds a piece of paper 3.0 cm. outside window #1, he finds that a sharp image of the object is formed on the paper and that it is smaller than the object. On the basis of this observation and of the initial observation, the satisfactory models are

A I and II only. **C** I and III only.
B III and IV only. **D** II and IV only.
E I, II, III, and IV.

35 As a further check, the observer makes a small hole through the top of the box and fills the box with a liquid of index of refraction 1.50. He then notices that when he looks into window #1, he sees straight through the box to window #3, and when he looks into window #2, he sees straight through the box to window #4.

Which of the originally proposed models is satisfactory on the basis of *all* of the observations?

A I and II **C** I only
B I and III **D** III only
E IV only

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Test 4
Part 2
Chapters 16-19

TESTS OF THE

PHYSICAL SCIENCE STUDY COMMITTEE

TEST 4: Light and Wave Motion

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

A Mass
B Time
C Length
D Density
E Force

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO

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Directions: Questions **1-8** are about a number of physical occurrences. Each of the lettered headings lists two or three classes of phenomena. For each occurrence, choose the heading that includes *all* the phenomena that are needed for an explanation of the *major features* of the occurrence and does *not* include any phenomenon unnecessary to the explanation.

A Reflection, interference
B Refraction, dispersion
C Interference
D Reflection, refraction, dispersion
E Reflection, refraction, interference

1 The appearance of a rainbow

2 The colored appearance of oil films on the pavement of a gas station, when they are viewed from directly above

3 The production of nodes in a ripple tank by means of a point source placed at the focus of a parabolic barrier

4 The production of nodes in a ripple tank by means of a point source placed inside an elliptical barrier

5 The colored appearance of the virtual image produced by a cheap, simple lens when light from an extended source of white light passes through it

6 The appearance of many colored images on examination of a neon sign viewed through a piece of flat glass ruled with evenly spaced parallel scratches which are close together

7 The appearance of colors when white light passes through a thick piece of glass with non-parallel faces

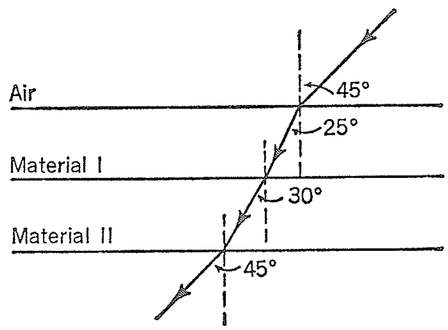
8 The pattern of light and dark bands on a screen illuminated both by a point source and by the image of the point source in a plane mirror of polished steel

GO ON TO THE NEXT PAGE

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the answer sheet.

Questions **9-15** relate to the following information and diagram:

A pencil of light passes through two different transparent materials (I and II in the figure), as shown. The faces of the materials are plane and parallel.



9 The index of refraction of Material I is

A less than that of air and less than that of Material II.
B greater than that of air and less than that of Material II.
C greater than that of air and greater than that of Material II.
D less than that of air and greater than that of Material II.
E the same as that of air and that of Material II.

10 The speed of the light in Material I is

A less than in air and less than in Material II.
B greater than in air and less than in Material II.
C greater than in air and greater than in Material II.
D less than in air and greater than in Material II.
E the same as in air and in Material II.

11 The frequency of the light in Material I is

A less than in air and less than in Material II.
B greater than in air and less than in Material II.
C greater than in air and greater than in Material II.
D less than in air and greater than in Material II.
E the same as in air and in Material II.

12 The wave length of the light in Material I is

A less than in air and less than in Material II.
B greater than in air and less than in Material II.
C greater than in air and greater than in Material II.
D less than in air and greater than in Material II.
E the same as in air and in Material II.

13 The product of the frequency and the wave length in Material I is

A less than in air and less than in Material II.
B greater than in air and less than in Material II.
C greater than in air and greater than in Material II.
D less than in air and greater than in Material II.
E the same as in air and in Material II.

14 The angle between the wave crests in Material I and the faces of the material is

A 25°
B 35°
C 45°
D 55°
E 65°

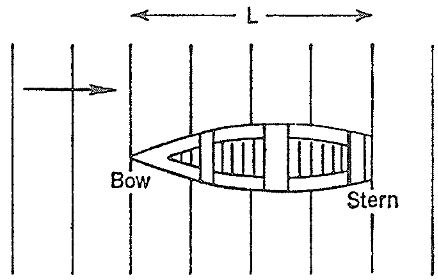
15 Suppose that the speeds of light in Materials I and II have been measured. When these data are combined with the directions of the pencil of light as shown in the figure, the combined information would be expected to

A support the particle model of light more than the wave model.
B support the wave model of light more than the particle model.
C support both the wave and particle models of light.
D support neither the wave nor the particle model of light.
E have bearing on neither the particle model nor the wave model of light.

GO ON TO THE NEXT PAGE

Questions **16-21** relate to the following situation:

A boat of length L is anchored in a lake in such a way that it is directly facing the oncoming water waves. The number of complete waves passing the bow of the boat per unit time is n. The maximum number of wave crests ever located under the boat occurs when a crest is at the bow of the boat and another is at the stern. This maximum number is m ($m = 5$ in the diagram below).



16 The wave length of the water waves is

A $\frac{L}{m-1}$
B $\frac{L}{m}$
C $\frac{L}{n-1}$
D $\frac{L}{n}$
E none of these

17 The number of complete waves passing the stern of the boat in a time t is

A m
B n
C $(m-1)t$
D nt
E $2nt$

18 The speed of the water waves relative to the bottom of the lake is

A $\frac{Ln}{m}$
B $\frac{2Ln}{m}$
C $\frac{Ln}{2(m-1)}$
D $\frac{Ln}{m-1}$
E $\frac{2Ln}{m-1}$

19 If the boat now moves directly against the waves with speed v relative to the bottom, the speed of the water waves relative to an observer on the boat is

A v
B $\frac{Ln}{m}$
C $\frac{2Ln}{m-1}$
D $v - \frac{Ln}{m-1}$
E $v + \frac{Ln}{m-1}$

20 If the boat moves as in question **19**, the maximum number of wave crests ever located under the boat is

A m
B $m+1$
C $m-1$
D $m + \frac{v}{nL}$
E $m - \frac{v}{nL}$

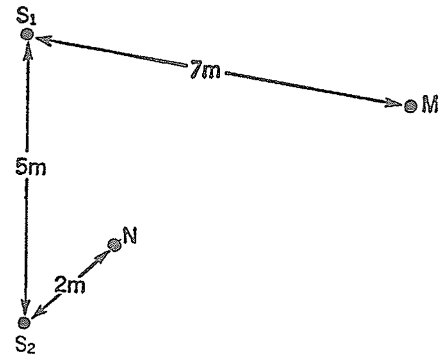
21 If the boat moves as in question **19**, the number of waves passing under the bow of the boat in unit time is

A n
B $2n$
C $(n-1) + \frac{m}{L}v$
D $n - \frac{(m-1)}{L}v$
E $n + \frac{m-1}{L}v$

GO ON TO THE NEXT PAGE

Questions **22-25** relate to the following information and diagram:

Two very small identical loudspeakers, each of which is radiating sound uniformly in all directions, are placed at points S_1 and S_2 as shown in the diagram. They are connected to a source so that they radiate in phase with each other, the wave length of the sound emitted being 2.00 meter. The speed of sound may be taken as 300 meters/second.



22 The frequency of the radiated sound is

A 600/sec
B 300/sec
C 150/sec
D 120/sec
E none of these

23 A microphone capable of detecting sound of 150 cycles/second is moved slowly from S_1 to S_2. At which of the following distances from S_1 will the microphone detect the smallest signal?

A ½ meter
B 1 meter
C 1½ meter
D 2 meter
E 2½ meter

24 Point M, a nodal point, is 7 meters from S_1 and at least 7 meters from S_2. The smallest distance that M can be from S_2 is

A 7 meter
B 8 meter
C 9 meter
D 10 meter
E 12 meter

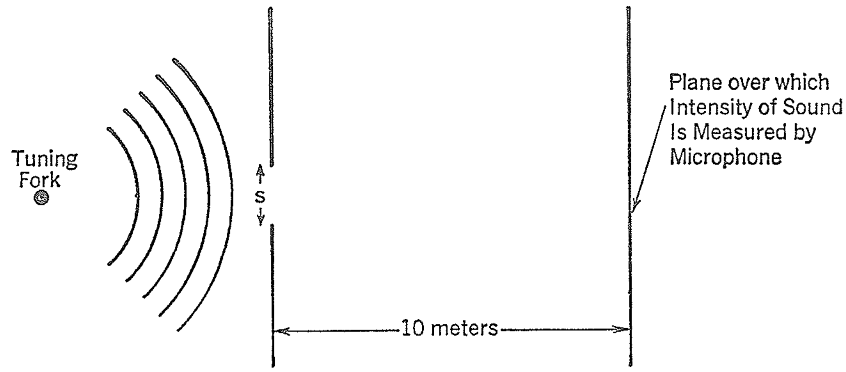
25 Suppose that loudspeaker S_2 is adjusted so that it radiates out of phase with S_1, the phase delay of S_2 with respect to S_1 being ½. Point N, which is 2 meters from S_2, will be a nodal point if its distance from S_1 is

A 2 meter
B 3 meter
C 4 meter
D 5 meter
E 7 meter

GO ON TO THE NEXT PAGE

Questions **26-29** relate to the following information and diagram:

In order to investigate the properties of sound waves, a student arranges to pass sound through a slit and to observe diffraction effects. The sound, whose speed in air is approximately 350 meters/second, is generated by means of a tuning fork vibrating at a frequency of 700 cycles/second. The intensity of the sound is measured by means of a microphone which can be moved over a plane parallel to the plane of the slit and at a distance of 10.0 meters from it.



26 The wave length in air of the sound generated by the tuning fork is

A 0.01 meter
B 0.25 meter
C 0.50 meter
D 1.0 meter
E 2.0 meter

27 If the slit width is 4.0 meters, what is the distance which one would expect to find between the central maximum and the minimum that is closest to it?

A 0.63 meter
B 1.3 meter
C 2.5 meter
D 20 meter
E 40 meter

28 If the experiment were carried out with light waves of wave length 10^{-7} meter and it were desired to obtain a distribution of light intensity over the plane exhibiting the same maxima and minima as the distribution of sound previously found, the slit width would need to be changed from 4.0 meters to how many meters?

A 8×10^{-1}
B 8×10^{-2}
C 8×10^{-4}
D 8×10^{-7}
E 8×10^{-8}

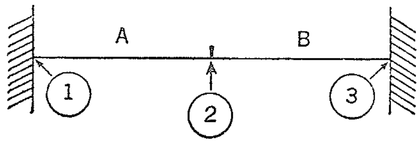
29 The speed of light is 3×10^{8} meters/second. The frequency of the light in question **28** is

A 3×10^{10} cycles/sec
B 3×10^{12} cycles/sec
C 3×10^{14} cycles/sec
D 3×10^{15} cycles/sec
E 3×10^{17} cycles/sec

GO ON TO THE NEXT PAGE

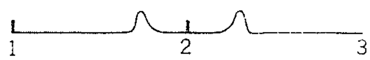
Questions **30-32** relate to the following information and diagrams:

A and *B* represent two cords of equal length tied together at point 2 and tied down at points *1* and *3*.

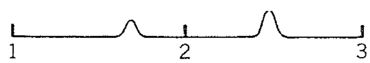


The diagrams numbered **30-32** show various pulses traveling along the cords. In each case, the pulses were produced by a single blow, and no reflection has taken place at either end.

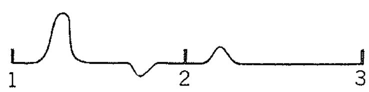
30



31



32



In answering each of questions **30-32**, select the condition which could account for the pulses appearing in the diagram bearing the same number as the question.

30 Under which of the following conditions could the pulses in diagram **30** have appeared?

- **A** *A* is heavier than *B*, and the blow was struck at *1*.
- **B** *A* is heavier than *B*, and the blow was struck at *3*.
- **C** *A* has the same weight as *B*, and the blow was struck at **2**.
- **D** *A* is lighter than *B*, and the blow was struck at *1*.
- **E** *A* is lighter than *B*, and the blow was struck at *3*.

31 Under which of the following conditions could the pulses in diagram **31** have appeared?

- **A** *A* and *B* are equally heavy, and the blow was struck at **2**.
- **B** *A* is heavier than *B*, and the blow was struck at *1*.
- **C** *A* is heavier than *B*, and the blow was struck at *3*.
- **D** *A* is lighter than *B*, and the blow was struck at *1*.
- **E** *A* is lighter than *B*, and the blow was struck between *1* and **2**.

32 Under which of the following conditions could the pulses in diagram **32** have appeared?

- **A** *A* is heavier than *B*, and the blow was struck at *1*.
- **B** *A* is heavier than *B*, and the blow was struck between *1* and **2**.
- **C** *A* is lighter than *B*, and the blow was struck at *1*.
- **D** *A* is lighter than *B*, and the blow was struck between *1* and **2**.
- **E** *A* is lighter than *B*, and the blow was struck at **2**.

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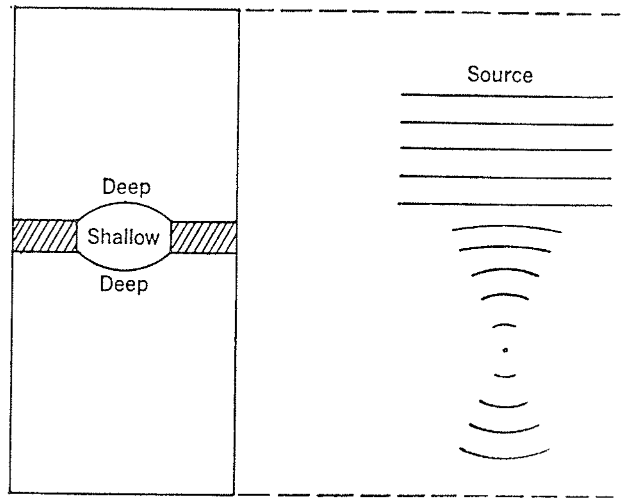
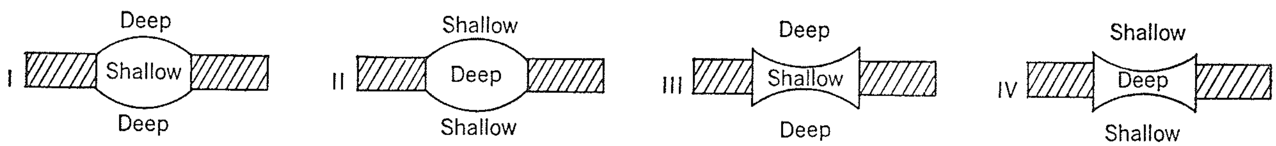
Questions **33-35** relate to the following diagrams and information:



When a ripple tank is arranged as shown above on the left, the wave pattern shown on the right is observed. The tank is now changed so that it contains any one of the arrangements shown below. In each case the regions labeled "deep" are of the same depth as were the deep sections above, and the regions labeled "shallow" are of the same depth as was the shallow section above.



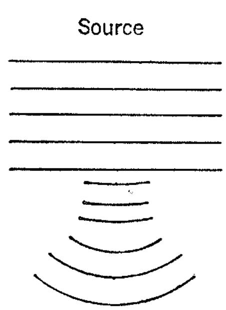
For each of the following items, select the arrangement that could produce the wave pattern in question. (In each case the wave generator could be either a straight line source or a point source.)

33 Arrangements that could produce patterns in which waves from a straight line source are focused to a point are

A I only.
B either I or II.
C either I or III.
D either I or IV.
E I, II, III, or IV.

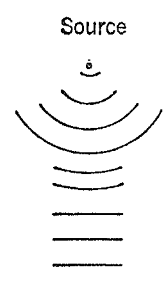
34 The wave pattern below could be produced by

A II only.
B III only.
C IV only.
D II or III.
E III or IV.



35 The wave pattern below could be produced by

A I only.
B II only.
C IV only.
D I or III.
E I or IV.



IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Test 5
Parts 1-2

TESTS OF THE

PHYSICAL SCIENCE STUDY COMMITTEE

TEST 5: Comprehensive Test on Parts 1 and 2

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

A Mass
B Time
C Length
D Density
E Force

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Questions **1-5** relate to the following information:

A merry-go-round rotating at constant speed makes one complete revolution every ten seconds. It has a rin[g] of horses mounted at a distance of 20 feet from the center and a ring of swans mounted at a distance of 10 fee[t] from the center. The frequency of any rotating object is defined as the number of revolutions that the objec[t] makes per unit time.

1 What is the frequency at which the horses are rotating?

A $\frac{1}{10}$ rev/sec
B $\frac{1}{2}$ rev/sec
C 1 rev/sec
D 10 rev/sec
E 2π rev/sec

2 The ratio of the frequency of rotation of the horses to that of the swans is

A $1:2\pi$
B 1:2
C 1:1
D $\sqrt{2}:1$
E 2:1

3 What is the ratio of the speed of the horses to that of the swans (both relative to the ground)?

A 1:2
B $1:\sqrt{2}$
C 1:1
D $\sqrt{2}:1$
E 2:1

4 If the frequency of the merry-go-round is f an[d] the distance of a horse from the center is r, wha[t] is the area swept out per unit time by a lin[e] connecting the horse to the center?

A $\pi r f$
B $2\pi r f$
C $\pi r^2 f$
D $2\pi r^2 f$
E $\pi r^2 f^2$

5 The speed of the merry-go-round is changed s[o] that it rotates steadily at $\frac{1}{20}$ revolution pe[r] second. An attendant walks on the rotating plat- form in a direction opposite to that of rotation. The attendant completes a trip from some par- ticular horse back to the same horse in 2[0] seconds. The frequency of rotation of th[e] attendant relative to the ground is

A 0 rev/sec
B $\frac{1}{20}$ rev/sec
C $\frac{1}{10}$ rev/sec
D 4π rev/sec
E 8π rev/sec

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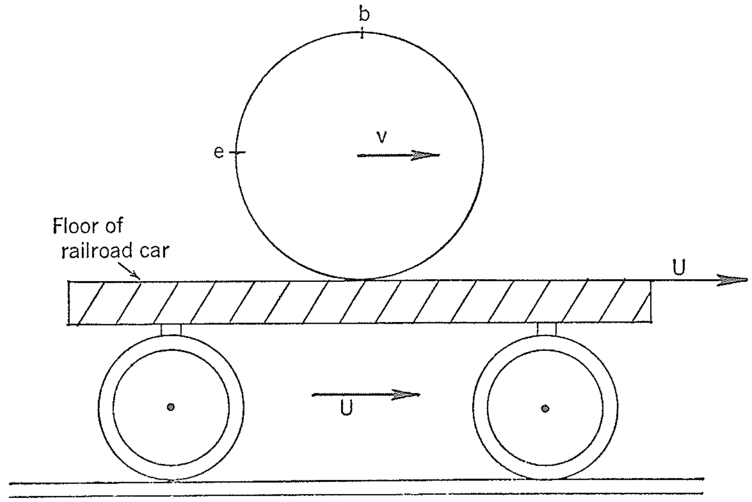
Questions **6-9** relate to the following diagram and information:



The wheel shown above is rolling, at a constant velocity $\vec{v}$, without slipping, with respect to the floor of a railroad car. The car is moving along a track with a constant velocity $\vec{U}$. $\vec{U}$ and $\vec{v}$ are in the same direction.

6 *With respect to the railroad car*, the instantaneous velocity of point b is

A zero
B of magnitude v and direction →
C of magnitude v and direction ←
D of magnitude $2v$ and direction →
E of magnitude $2v$ and direction ←

7 *With respect to the railroad car*, the instantaneous velocity of point e is

A zero
B in the direction ↑
C in the direction ↗
D in the direction →
E none of the above

8 *With respect to the railroad car*, the instantaneous *acceleration* of point b is in the direction

A →
B ↓
C ←
D ↑
E not specified, because its magnitude is zero

9 The instantaneous velocity of the center of the wheel, *relative to the track*, can be expressed as

I $\vec{v} + \vec{U}$
II $\vec{v} - \vec{U}$
III $v + U$ in the direction →
IV $v - U$ in the direction →

A I and III only
B II and IV only
C I, II, and III only
D I, II, III, and IV
E II, III, and IV only

GO ON TO THE NEXT PAGE

Questions **10-13** relate to the following information:

The greatest total mass (plane plus load) that can be supported by any airplane is given by the equation $M = kdAV^2$, where k is a number that depends on the shape of the airplane, d is the density of the layer of air through which the airplane is moving, A is the area of the airplane's wings, and V is the speed of the airplane relative to the air.

10 Two airplanes that have identical shapes are built of the same materials. All the linear dimensions of the first airplane are twice as great as the corresponding linear dimensions of the second airplane. What is the ratio of the mass of the larger unloaded airplane to that of the smaller?

A 2:1
B 4:1
C 8:1
D 16:1
E It cannot be determined from the information given.

11 What is the ratio of the area of the wings of the larger airplane in Question **10** to the area of the wings of the smaller?

A 2:1
B 4:1
C 8:1
D 16:1
E It cannot be determined from the information given.

12 An engineer builds an exact scale model of a certain airplane and tests it in a wind tunnel in which the pressure and the temperature of the air are the same as those that the airplane will encounter in flight. The linear dimensions of the model are $1/100$ of those of the airplane. The engineer finds that the model can support a total mass of 1.0 kg. when its speed relative to the air is 100 km/hr. On the basis of this result, he predicts the maximum total mass which the airplane will be able to support when flying at 200 km/hr. This mass is about

A $\sqrt{2} \times 10^4$ kg.
B 2×10^4 kg.
C 4×10^2 kg.
D 4×10^3 kg.
E 4×10^4 kg.

13 If the mass of the airplane in Question **12** is to be 1.0×10^4 kg., the data obtained with the model indicate that the minimum speed at which the airplane will be able to fly is approximately

A 100 km/hr
B 200 km/hr
C 300 km/hr
D 400 km/hr
E 500 km/hr

Questions **14-17** relate to the following table, which shows the chemical analyses of samples of three chemical compounds:

Compound	Mass of sample, in grams	Mass, in grams, of elements in sample		
		Element X	Element Y	Element Z
I	70	40	30	0
II	80	0	30	50
III	105	20	60	25

GO ON TO THE NEXT PAGE

14 If 20 grams of element X are reacted with 40 grams of element Y, what will be the amount of compound I formed?

A 15 grams
B 25 grams
C 35 grams
D 40 grams
E 60 grams

15 If 50 grams of element X are reacted with 150 grams of element Y and 50 grams of element Z, what is the maximum amount of compound III which can be formed?

A 90 grams
B 130 grams
C 170 grams
D 210 grams
E 250 grams

16 If, in addition to the formation of compound III in Question **15**, compound I can also be formed from the excess reacting elements, what amount of compound I can be formed?

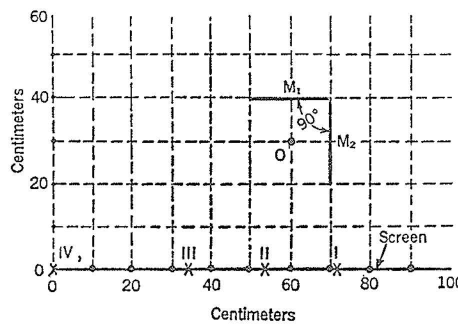
A 7.5 grams
B 17.5 grams
C 22.5 grams
D 30 grams
E 40 grams

17 If the chemical formula of compound I is known to be X_2Y_2, what is the ratio of the atomic mass of X to that of Y?

A 1:2
B 2:3
C 4:3
D 2:1
E 8:3

Questions **18-21** relate to the following information and diagram:

Each of the mirrors M_1 and M_2 shown in the diagram is vertical and 20 cm. by 20 cm. in size. A small luminous source O is located 10 cm. in front of the center of M_1. Small peepholes are pierced in a screen at the positions marked x and identified by Roman numerals in the diagram. The screen stands parallel to mirror M_1 and 40 cm. from it. All the holes are at the same height as the luminous source O.



18 What is the maximum number of images that an observer looking through hole II will be able to see?

A 0
B 1
C 2
D 3
E 4

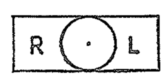
19 What is the maximum number of images that an observer looking through hole I will be able to see?

A 0
B 1
C 2
D 3
E 4

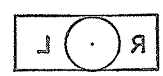
20 What is the maximum number of images that an observer looking through hole IV will be able to see?

A 0
B 1
C 2
D 3
E 4

21 The side of source O which is facing mirror M_1 looks like *1* below.



1

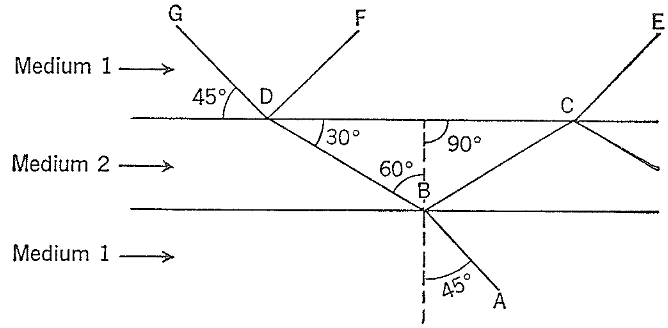

2

Suppose now that an observer looks through one of the holes in the screen and that he sees at least one image of O. Then each image that he sees must look either like *1* or like *2* above. If the observer sees exactly three images of O, how many of these images look like *2*?

A 0
B 1
C 2
D 3
E It cannot be determined from the information given.

GO ON TO THE NEXT PAGE

Questions **22-23** relate to the following diagram, which shows all the light rays incident upon and emergent from a plate of transparent material having parallel faces.



22 Which of the following could be the incident ray?

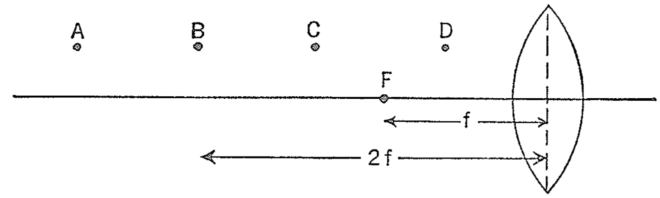
A *AB*
B *EC*
C *FD*
D *GD*
E It cannot be determined from the information given.

23 The index of refraction of Medium 2 relative to Medium 1 is

A $\frac{\sin 30°}{\sin 45°}$
B $\frac{\sin 45°}{\sin 60°}$
C $\frac{\sin 60°}{\sin 45°}$
D $\frac{\sin 45°}{\sin 30°}$
E none of these

Questions **24-25** relate to the following information and diagram:

Points *A*, *B*, *C*, and *D* are possible positions of objects for the lens shown in the diagram below. Point *F* is the position of the principal focus which is on the near side of the lens.



24 Which object position gives an image which is real, inverted, and larger than the object?

A *A*
B *B*
C *C*
D *D*
E none of the above

25 Which object position gives an image which is virtual, inverted, and of the same size as the object?

A *A*
B *B*
C *C*
D *D*
E none of the above

GO ON TO THE NEXT PAGE

Questions **26-28** relate to light incident on a thin film of glass. The frequency and the wave length of the light in the air are denoted by f_a and λ_a, respectively. The index of refraction of the glass is denoted by n_g.
It is an experimental fact that light reflected in air from a glass surface undergoes a phase delay of ½.

26 Which of the following is equal to the frequency of the light in the glass?

A $\frac{f_a}{n_g}$
B $\frac{f_a}{n_g - 1}$
C $(n_g - 1)f_a$
D f_a
E $n_g f_a$

27 Which of the following is equal to the wave length of the light in the glass?

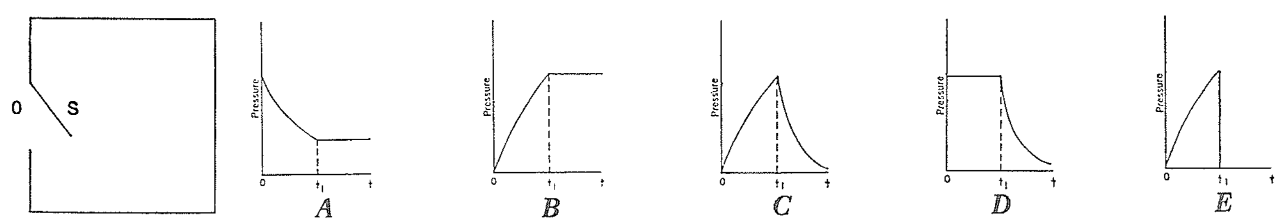
A $\frac{\lambda_a}{n_g}$
B $\frac{\lambda_a}{\sqrt{n_g}}$
C λ_a
D $\sqrt{n_g}\lambda_a$
E $n_g \lambda_a$

28 Orange light with $\lambda_a = 6.000 \times 10^3$ Å (Angstroms) is incident normally from air onto a glass film whose index of refraction is 1.50. For what value of film thickness will the greatest amount of light be transmitted through the film?

A 1.000×10^3 Å
B 1.00×10^3 Å
C 2.000×10^3 Å
D 2.00×10^3 Å
E 3.00×10^3 Å

Questions **29-31** relate to the following information, diagram, and graphs:

The diagram shows a box whose inner walls are perfect reflectors. The box is provided with a small shutter S which, when open, allows light from a source O to enter the box. The box is evacuated so that molecular pressure is negligible when compared with the pressure due to the light. In answering the following questions, consider that the light pressure can be explained by means of the particle model of light.



29 Suppose that initially the shutter is open, the box is in a dark room, and the source is off. At time $t = 0$, the source is turned on; at time $t = t_1$ the shutter is closed. The graph that might represent the pressure inside the box as a function of time is

A *A*
B *B*
C *C*
D *D*
E *E*

30 Suppose that at $t = 0$ the source has been on and the shutter open for some time. At $t = t_1$ the source is turned off, the shutter being left open. The graph that might represent the pressure inside the box as a function of time is

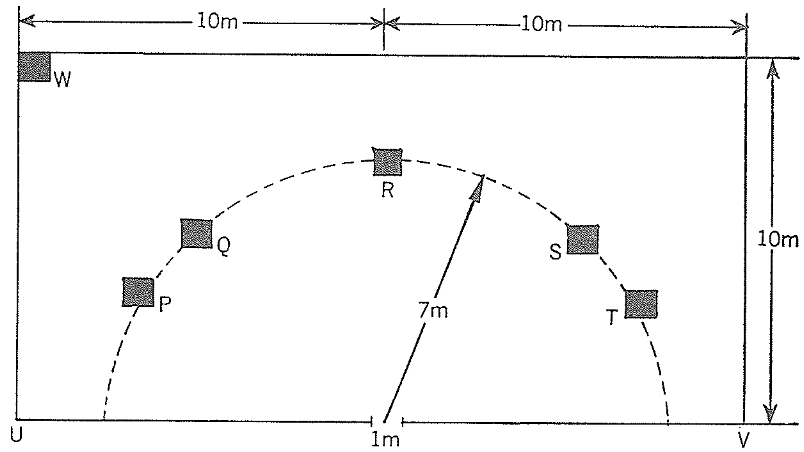
A *A*
B *B*
C *C*
D *D*
E *E*

31 With a source of red light at O, it is found that the pressure in the box begins to increase when the shutter is opened and increases until it reaches some value P_r. It then remains steady. With a source of blue light at O, the pressure behaves similarly, except that the steady pressure P_b is greater than P_r. From these observations, it is certain that

A blue particles move faster than red particles.
B blue particles are more massive than red particles.
C the blue source gives off more particles per second than does the red source.
D when the pressure is steady at either P_r or P_b, particles are leaving the box at the same rate as they are entering it.
E when the pressure is P_r, particles enter the box at the same rate as when the pressure is P_b.

Questions **32-35** refer to the following information and diagram:

A large rectangular room has the dimensions shown below and walls that absorb light, sound, and radio wave completely. *P*, *Q*, *R*, *S*, *T*, and *W* are devices capable of detecting any of these three kinds of waves. Th opening in the center of the wall *UV* is 1 meter wide. Radio and light waves travel at a speed of 3.0×10 meters/second, and sound waves travel at a speed of 3.6×10^2 meters/second.



32 Suppose that light from a very distant source is falling on the wall *UV* normally. If the wave length of this light is 6×10^{-7} meter, which of the devices mentioned below can be expected to respond?

A *R* only
B *Q* and *R* only
C *R* and *S* only
D *Q*, *R*, and *S* only
E *P*, *Q*, *R*, *S*, and *T*

33 If, instead of light, radio waves of wave length 200 meters are falling normally on the wall *UV*, which of the devices mentioned below can be expected to respond?

A *R* only
B *Q* and *R* only
C *R* and *S* only
D *Q*, *R*, and *S* only
E *P*, *Q*, *R*, *S*, and *T*

34 Sound waves of frequency 24,000 cycles/second are now used. Which of the devices mentioned below can be expected to respond?

A *R* only
B *Q* and *R* only
C *R* and *S* only
D *Q*, *R*, and *S* only
E *P*, *Q*, *R*, *S*, and *T*

35 Suppose that radio waves of frequency 10^6 cycles/second are now used. In which of the following groups are there devices which will NOT receive approximately equal signals?

A *Q* and *R*
B *Q* and *S*
C *R* and *S*
D *P* and *R*
E *S* and *W*

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Test 6
Part 3
Chapters 20-23

TESTS OF THE PHYSICAL SCIENCE STUDY COMMITTEE

TEST 6: Force and Momentum

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

A Mass
B Time
C Length
D Density
E Force

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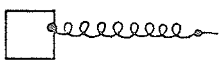
Part I

Directions: The items in this part of the test consist of five lettered answer choices followed by a list of numbere questions. For each question select the one lettered answer which is most closely related to it and blacken th corresponding space on the answer sheet. An answer may be used once, more than once, or not at all.

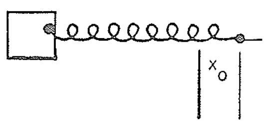
Questions **1-5** relate to the following information and diagrams:

Several identical springs and several identical masses are used to perform acceleration experiments on a frictionless surface. It is found that a single spring, when extended by an amount x_0, gives an acceleration a_0 to a single mass.

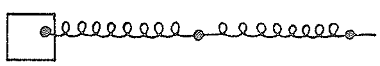
Single spring: unextended



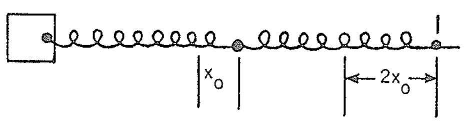
Single spring: extended x_0



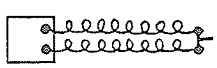
Two springs connected end-to-end: unextended



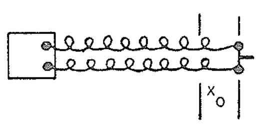
Two springs connected end-to-end: extended total amount $2x_0$



Two springs connected side-by-side: unextended



Two springs connected side-by-side: extended x_0



A $\frac{1}{2}a_0$
B a_0
C $2a_0$
D $4a_0$
E Cannot be determined without addition information

1 What acceleration would be produced on single mass by two springs connected side-by side and extended by an amount x_0?

2 What acceleration would be produced on a sing mass by two springs connected end-to-end an extended by a total amount $2x_0$?

3 What acceleration would be produced on two o the masses tied together if two springs ar connected end-to-end and extended by a tot amount $2x_0$?

4 What acceleration would be produced on two o the masses tied together if four springs ar connected side-by-side and the combination extended by an amount x_0?

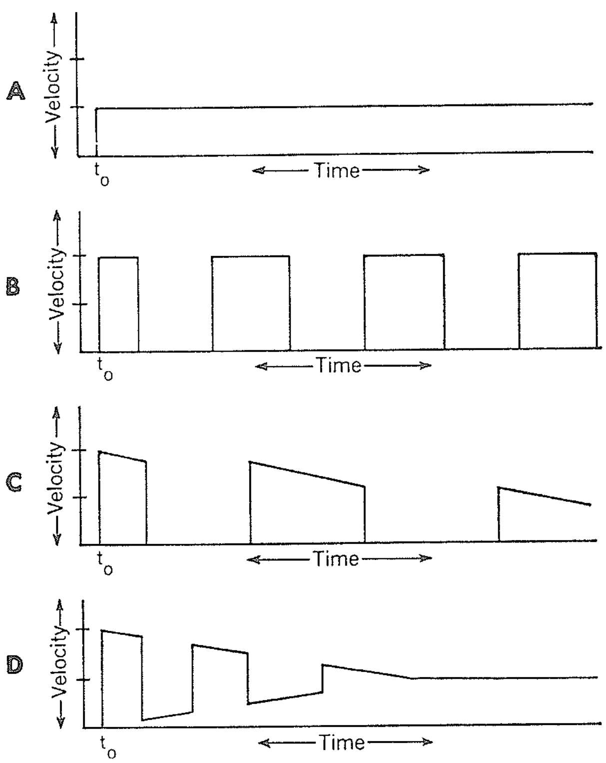
5 Two springs are connected side-by-side; th combination is then connected end-to-end to a identical combination. What acceleration woul be produced on a single mass if this arrangemen of springs is extended by a total amount $2x_0$

GO ON TO THE NEXT PAG

Questions **6-12** relate to the following information and graphs:

A standard impulse is given at time t_0 to each of several closed boxes having identical masses and identical appearance. The impulse starts the box into motion on a horizontal plane. There may or may not be friction (referred to as "external friction") between any box and the plane. It is known that each box contains a disc whose mass is equal to that of the box and which is resting on the bottom of the inside of the box. There may or may not be friction (referred to as "internal friction") between any disc and the bottom of its box. The discs may rebound in a perfectly elastic way from the walls of the box ("elastic walls"), or they may stick to the walls on colliding ("sticky walls").

The graphs below show the velocities of various boxes as a function of time.



E None of the above

6 Which of the graphs could represent the velocity-time relationship of a box with no external friction and whose disc is fastened solidly to the box?

7 Which of the graphs could represent the velocity-time relationship of the same box *with* external friction?

8 A box with elastic walls and no internal or external friction has its disc initially resting in the middle of the box. Which of the graphs could represent the velocity-time relationship of this combination?

9 A box with sticky walls and no internal or external friction has its disc initially resting in the middle of the box. Which of the graphs could represent the velocity-time relationship of this combination?

10 A box with elastic walls and no internal friction, but *with* external friction, has its disc initially resting in the middle of the box. Which of the graphs could represent the velocity-time relationship of this combination?

11 A box with elastic walls, and *with* internal friction, but with *no* external friction, has its disc initially resting in the middle of the box. Which of the graphs could represent the velocity-time relationship of this combination?

12 A box with elastic walls and no internal or external friction has its disc initially resting very near the end of the box that is struck. Which of the graphs could represent the velocity-time relationship of this combination?

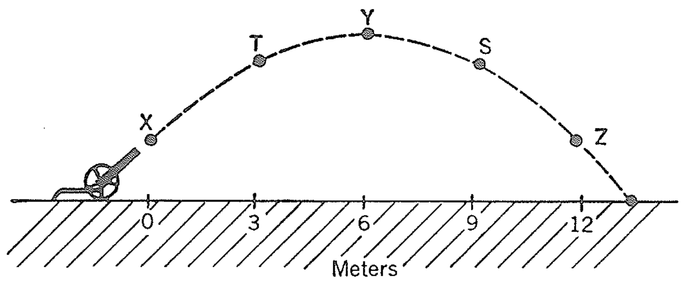
GO ON TO THE NEXT PAGE

Part II

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the answer sheet.

Questions **13-16** relate to the following information and projectile graph.

The graph below shows the path of a projectile fired by a toy cannon. In answering the related questions, assume frictional forces to be negligible.



13 The *speed* of the projectile as it leaves the toy cannon is the same as its speed at

A *T*
B *Y*
C *S*
D *Z*
E none of the above.

14 The *horizontal* component of the momentum of the projectile after it leaves the muzzle of the toy cannon is

A greatest at point *X*.
B greatest at point *T*.
C greatest at point *Y*.
D greatest at point *Z*.
E the same at all points.

15 The *vertical* component of the momentum is zero at

A *X*
B *T*
C *Y*
D *Z*
E none of the above.

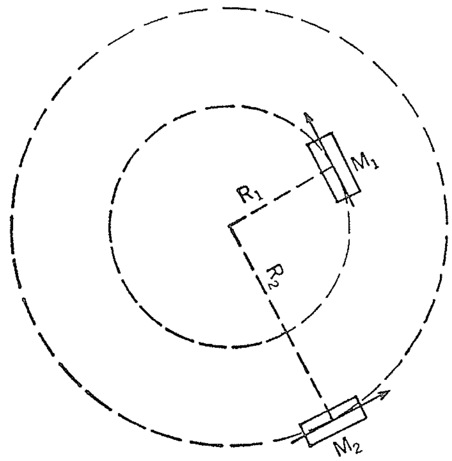
16 The *momentum* of the projectile as it leaves the toy cannon is the same as its momentum at

A *T*
B *Y*
C *S*
D *Z*
E none of the above.

GO ON TO THE NEXT PAGE

Questions **17-20** relate to the following information and diagram:

Two racing cars of masses M_1 and M_2 are moving in circles of radii R_1 and R_2 as shown. Their speeds are such that they each make a complete circle in the same length of time T.



17 The ratio of the *angular* speed (measured in degrees of arc per second) of the first car to that of the second car is

A 1:1
B $M_1:M_2$
C $M_2:M_1$
D $R_1:R_2$
E $R_2:R_1$

18 The ratio of the speed measured in meters per second of the first car to that of the second car is

A 1:1
B $M_1:M_2$
C $M_2:M_1$
D $R_1:R_2$
E $R_2:R_1$

19 The ratio of the centripetal acceleration of the first car to that of the second car is

A 1:1
B $M_1:M_2$
C $M_2:M_1$
D $R_1:R_2$
E $R_2:R_1$

20 The ratio of the centripetal force acting on the first car to that acting on the second car is

A 1:1
B $M_1R_1:M_2R_2$
C $M_1R_2:M_2R_1$
D $M_2R_2:M_1R_1$
E $M_2R_1:M_2R_2$

GO ON TO THE NEXT PAGE

Questions **21-26** relate to the following situation:

A rocket has an initial mass of 100 kilograms, 90 per cent of which is fuel. This fuel is turned to gas and ejected from the rocket at a rate of 1 kilogram per second. The velocity of fuel ejection is 500 meters per second *relative to the rocket.* Suppose that this rocket is fired in the absence of any gravitational field.

21 The force on the rocket when it is just starting to move is

A 0
B 5.0×10^2 newtons
C 10^3 newtons
D 2.0×10^2 newtons
E 10^4 newtons

22 The force on the rocket after 50 seconds is

A 0
B 5.0×10^2 newtons
C 10^3 newtons
D 2.0×10^2 newtons
E 10^4 newtons

23 The acceleration of the rocket after 50 seconds is

A 0
B 2.5 meters/sec^2
C 5.0 meters/sec^2
D 10 meters/sec^2
E 20 meters/sec^2

24 After 5 seconds the velocity of the rocket will be approximately

A 12 meters/sec
B 25 meters/sec
C 50 meters/sec
D 100 meters/sec
E 200 meters/sec

25 The distance covered by the rocket in the first 5 seconds will be approximately

A 65 meters
B 120 meters
C 250 meters
D 500 meters
E 2500 meters

26 What is the acceleration *immediately after* all the fuel is burned?

A 0
B 2.5 meters/sec^2
C 5.0 meters/sec^2
D 10 meters/sec^2
E 20 meters/sec^2

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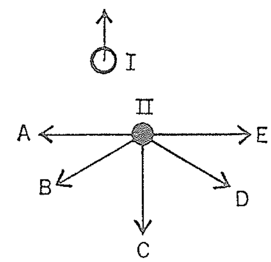
Questions **27-30** relate to the following information and diagrams:

A ball (I) having a mass of 1.0 kg and moving at a speed of 4.0 meter/second strikes a glancing blow on a second ball (II). After the collision, ball I is moving at right angles to its original direction of motion, as shown in the diagram, with a speed of 3.0 meter/second.

Before collision

After collision



27 The direction of motion of ball II after the collision might be represented by the arrow labeled

A *A*
B *B*
C *C*
D *D*
E *E*

28 The momentum of ball II after the collision has a magnitude

A 1.0 kg meter/sec
B 2.0 kg meter/sec
C 3.0 kg meter/sec
D 4.0 kg meter/sec
E 5.0 kg meter/sec

29 It is found that the speed of ball II after the collision is 1.25 meter/second. The mass of ball II is

A greater than 2.0 kg
B between 1.0 kg and 2.0 kg
C equal to 1.0 kg
D between 0.5 kg and 1.0 kg
E less than 0.5 kg

30 The force acting on ball II during the collision is

A 5.0 newtons.
B 2.5 newtons.
C 10 newtons.
D equal to the gravitational force between the two balls when their centers are separated by the sum of their radii.
E not determinable by the information given.

GO ON TO THE NEXT PAGE

Questions **31-35** relate to the following information:

In answering the numbered questions below, you will need to make use of the following definitions in addition to what you have learned about the solar system.

Definitions:

aphelion – that point in a planet's orbit which is farthest from the sun

total solar eclipse – phenomenon caused by the moon's passing directly between the sun and the earth so that the umbra of the moon's shadow reaches the earth's surface

perihelion – that point in a planet's orbit which is closest to the sun. The earth is at perihelion on January 4.

transit – the apparent passage of a smaller celestial body across the disc of a larger celestial body, such as the passage of the planet Venus across the sun's disc

31 In what month is the *apparent* diameter of the sun the largest as seen from the earth?

A June
B July
C December
D January
E None of the above

32 In what month is the earth moving most slowly in its orbit?

A June
B July
C December
D January
E None of the above

33 In what month does the earth travel farthest in its orbit during a given twenty-four hour period?

A June
B July
C December
D January
E None of the above

34 In what month must a total solar eclipse occur at a given region of the earth's surface, if the moon's umbra is to sweep out the widest possible path?

A June
B July
C December
D January
E None of the above

35 The orbit of the planet Venus is entirely inside the orbit of the earth. Assuming that two of the following statements can be true at the same time, which combination would cause Venus to appear largest during a transit of the sun, as seen from the earth?

I Earth is at perihelion.
II Earth is at aphelion.
III Venus is at perihelion.
IV Venus is at aphelion.

A I and III only
B II and IV only
C I and IV only
D II and III only
E None of the above

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Test 7
Part 3
Chapters 24-26

TESTS OF THE

PHYSICAL SCIENCE STUDY COMMITTEE

TEST 7: Energy

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

Sample Question

0 Which of the following is most directly measured by the use of a clock?

A Mass
B Time
C Length
D Density
E Force

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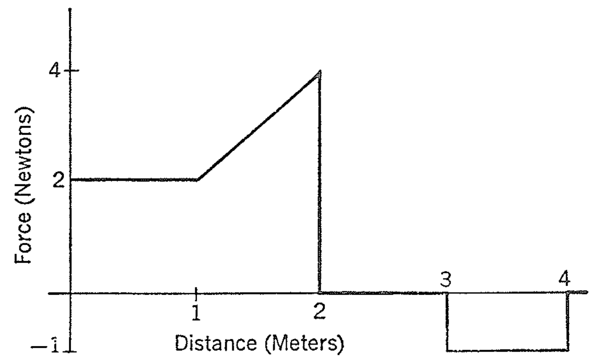
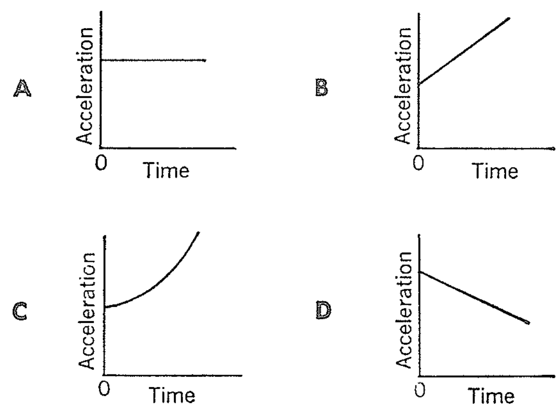
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the answer sheet.

Questions **1-5** relate to the following graph and information:



The graph above shows the force applied to a 2-kilogram body initially at rest but free to move on a horizontal frictionless surface.

1 Which one of the following graphs best represents the acceleration of the body during the first meter of travel?



E None of the above graphs

2 After the body has moved a distance of 1 meter its kinetic energy is

A 1 joule.
B 2 joules.
C 3 joules.
D 4 joules.
E 19.6 joules.

3 After the body has moved a distance of 2 meters its kinetic energy is

A 1 joule.
B 2 joules.
C 4 joules.
D 5 joules.
E 6 joules.

4 After the body has moved a distance of 3 meters its kinetic energy is

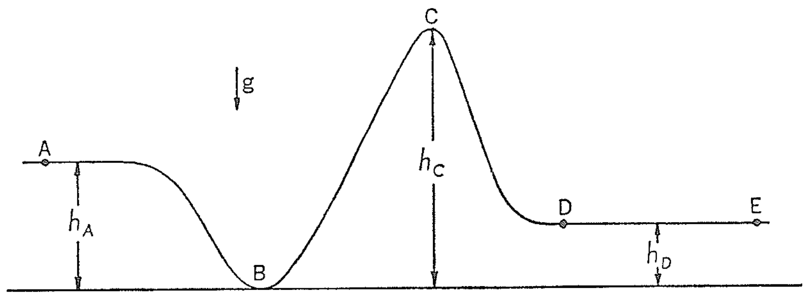
A 1 joule.
B 2 joules.
C 4 joules.
D 5 joules.
E 6 joules.

5 After the body has moved a distance of 4 meters its kinetic energy is

A 1 joule.
B 2 joules.
C 4 joules.
D 5 joules.
E 6 joules.

GO ON TO THE NEXT PAGE

Questions **6-10** relate to the following diagram and information:



The diagram shows the side view of a roller coaster track. A car of mass m can be placed at various points on the track and be given various initial velocities. Assume all frictional forces to be negligible. The acceleration due to gravity has a magnitude g and is directed downward, as shown.

6 If the car is placed at *C* and allowed to slide toward the left, starting from rest, its speed at *B* will be

A 0
B mgh_C
C $\sqrt{2gh_A}$
D $\sqrt{2gh_C}$
E $\sqrt{2g(h_C - h_A)}$

7 If the car is placed at *C* and allowed to slide toward the left, its speed at *A* will be

A 0
B mgh_C
C $\sqrt{2gh_A}$
D $\sqrt{2gh_C}$
E $\sqrt{2g(h_C - h_A)}$

8 If the car is placed at *A* and given an initial velocity toward the right just sufficient for it to reach point *C*, this initial velocity must have a magnitude of

A 0
B mgh_C
C $\sqrt{2gh_A}$
D $\sqrt{2gh_C}$
E $\sqrt{2g(h_C - h_A)}$

9 If the car is started from *A* toward the right and is given a kinetic energy equal to mgh_C, its speed at *D* will be

A $\sqrt{2gh_A}$
B $\sqrt{2gh_C}$
C $\sqrt{2gh_D}$
D $\sqrt{2g(h_A - h_D)}$
E $\sqrt{2gh_C + 2g(h_A - h_D)}$

10 If the car is started from *A* toward the right and is given a kinetic energy equal to mgh_C, its speed at *E* will be the same as its speed at

A point *A*.
B point *B*.
C point *C*.
D point *D*.
E none of the above.

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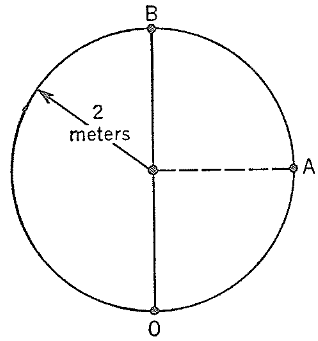
Questions **11-17** relate to the following information and diagram:

A cart is propelled from the left into a vertical "loop-the-loop" track, at the lowest point, *O*. The track has a radius of 2.0 meters, as shown in the diagram. The mass of the cart is 0.2 kilograms; all frictional forces may be neglected; and *g* may be taken as 10 meters per second per second.



11 If the speed of projection is 10 meters per second, what is the kinetic energy of the cart at this speed?

- **A** 2 joules
- **B** 10 joules
- **C** 20 joules
- **D** 200 joules
- **E** Impossible to determine from the data given

12 If the speed of projection is 10 meters per second, what is the potential energy of the cart at point *A* relative to its value at point *O*?

- **A** 2 joules
- **B** 4 joules
- **C** 10 joules
- **D** 20 joules
- **E** Impossible to determine from the data given

13 If the speed of projection is 10 meters per second, the speed of the cart at point *A* is

- **A** $\sqrt{10}$ meters/sec
- **B** $3\sqrt{10}$ meters/sec
- **C** $\sqrt{15}$ meters/sec
- **D** $2\sqrt{15}$ meters/sec
- **E** $\sqrt{20}$ meters/sec

14 Assuming that the cart still makes contact with the track at point *A*, what is the force exerted by the track on the cart?

- **A** $\sqrt{20}$ newtons
- **B** $2\sqrt{15}$ newtons
- **C** 6.0 newtons
- **D** 10.0 newtons
- **E** 30 newtons

15 If the speed of projection is such that the cart has only potential energy at the instant it reaches point *A*, what is its speed at point *A*?

- **A** Impossible to determine without knowing the initial speed
- **B** 0 meters/sec
- **C** 5 meters/sec
- **D** $2\sqrt{5}$ meters/sec
- **E** 20 meters/sec

16 If the speed of projection is such that the cart just starts to fall away from the track at point *B*, what is its speed at point *B*?

- **A** Impossible to determine without knowing the initial speed
- **B** 0 meters/sec
- **C** 5 meters/sec
- **D** $2\sqrt{5}$ meters/sec
- **E** 20 meters/sec

17 What is the minimum speed of projection which will cause the cart to reach point *B* without falling from the track?

- **A** $\sqrt{20}$ meters/sec
- **B** 10 meters/sec
- **C** $10\sqrt{15}$ meters/sec
- **D** 50 meters/sec
- **E** 100 meters/sec

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Questions **18-21** relate to the following information:

A sealed container, which expands negligibly as its temperature is changed, contains helium (a monatomic gas). It is heated from 300° Kelvin (27° Celsius) to 600° Kelvin (327° Celsius).

18 As a result of the increase in temperature, the average kinetic energy of the molecules has been

A halved.
B left unchanged.
C increased by a factor of $\sqrt{2}$.
D doubled.
E quadrupled.

19 As the temperature was raised, the average speed of the molecules has been

A halved.
B left unchanged.
C increased by a factor of $\sqrt{2}$.
D doubled.
E quadrupled.

20 As a result of the increase in temperature, the pressure exerted by the gas on the walls of the container has been

A halved.
B left unchanged.
C increased by a factor of $\sqrt{2}$.
D doubled.
E quadrupled.

21 With the container kept at 600° Kelvin, a valve is opened and some gas is allowed to escape. If the pressure is reduced to the value that it had at 300° Kelvin, it is necessary that

A $\frac{7}{8}$ of the molecules escape.
B $\frac{3}{4}$ of the molecules escape.
C $\frac{1}{2}$ of the molecules escape.
D $\frac{1}{4}$ of the molecules escape.
E something else be done, as the pressure cannot be reduced by this method alone.

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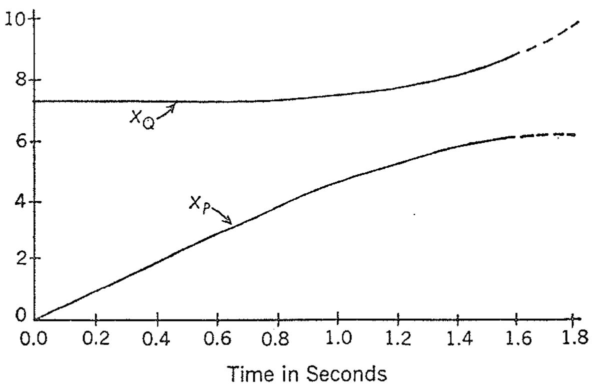
Questions **22-26** relate to the following information and graph:

A body P is projected along a horizontal straight line toward another body Q, in such a manner that it makes a "head-on" collision with body Q. Each body has a mass of 1.00 kilogram. All effects that might produce heat or permanent deformation of the bodies are negligible and any forces that may be acting depend only on the distance between the two bodies.

A stroboscopic photograph of the process is obtained and an analysis of it gives the data in the table below. The position and velocity of the body P are indicated by x_P and v_P respectively; those of Q by x_Q and v_Q respectively. The last two columns of the table give values of the squares of the velocities for your convenience, if you wish to use them in answering the questions.

Time (sec)	x_P (m)	x_Q (m)	v_P (m/sec)	v_Q (m/sec)	v_P^2 $(m/sec)^2$	v_Q^2 $(m/sec)^2$
0.00	0.00	7.50	5.00	0.00	25.0	0.00
0.20	1.00	7.50	5.00	0.00	25.0	0.00
0.40	2.00	7.50	5.00	0.00	25.0	0.00
0.60	3.00	7.50	4.95	0.05	24.5	0.002
0.80	3.95	7.54	4.56	0.44	21.8	0.19
1.00	4.80	7.70	3.86	1.14	14.8	1.30
1.20	5.48	8.02	2.91	2.09	8.46	4.37
1.40	5.97	8.53	1.97	3.03	3.88	9.19
1.60	6.30	9.20	1.29	3.71	1.66	13.76

The following graph shows the positions of bodies P and Q at various times before and during the major part of the collision:



22 The results shown in the table are consistent with the assumption that

A there is no force acting between P and Q.
B P and Q repel each other with a force that is independent of their separation.
C P and Q attract each other at distances less than about 5.00 m and repel each other at larger distances.
D P and Q exert no force on each other at distances greater than about 5.00 m and repel each other at smaller distances.
E P and Q repel each other at distances less than about 5.00 m and attract each other at greater distances.

23 Taking the potential energy of the system at $t = 0$ as zero, the total energy at $t = 0$ is

A 50.0 joule.
B 25.0 joule.
C 12.5 joule.
D zero.
E not determinable from the data.

24 If the total energy of the system at time 0.00 sec is denoted by E, the potential energy stored at time equal 1.00 sec is

A zero.
B equal to E.
C equal to E minus 14.8 joule.
D equal to E minus 8.05 joule.
E not determinable from the data.

25 The maximum value of the potential energy stored in the system occurs at a time

A 0.00 sec.
B 0.50 sec.
C between 0.50 sec and 1.00 sec.
D between 1.00 sec and 1.40 sec.
E greater than 1.40 sec.

26 After the collision between P and Q is over, the final values of v_P and v_Q can be expected to be

A $v_P = -5$m/sec, $v_Q = 0$m/sec.
B $v_P = -4$m/sec, $v_Q = 3$m/sec.
C $v_P = -1$m/sec, $v_Q = 6$m/sec.
D $v_P = 0$m/sec, $v_Q = 5$m/sec.
E $v_P = 1$m/sec, $v_Q = 4$m/sec.

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Questions **27-31** relate to the following situation:

A pile driver having a mass of 600 kilograms falls 5.0 meters on a pile of mass 200 kilograms. After impact the pile sinks 0.03 meter into the ground. Take the magnitude of g as 10 meters per second.

27 What is the speed of the pile driver when it reaches the pile?

- **A** $\sqrt{10}$ meters/sec
- **B** 20 meters/sec
- **C** $\sqrt{25}$ meters/sec
- **D** 10 meters/sec
- **E** $\sqrt{50}$ meters/sec

28 Assuming that the pile driver and the pile move together following impact, what is the ratio of the speed of this combination immediately after impact to the speed of the pile driver just before impact?

- **A** 1:4
- **B** 1:2
- **C** 3:4
- **D** 1:1
- **E** 3:1

29 If the initial height of the pile driver is changed so that the speed immediately after impact is 20 meters per second, it is found that the pile sinks 0.20 meter into the ground. Assuming that the pile driver and the pile move together following impact, what is the kinetic energy of pile and pile driver the instant after impact?

- **A** 1.6×10^4 joules
- **B** 1.6×10^5 joules
- **C** 10^6 joules
- **D** 10^4 joules
- **E** 8×10^4 joules

30 Under the conditions specified in Question 29, what is the loss in the potential energy of the pile and the pile driver during the time in which the pile is driven into the ground (that is, between the time of the impact and the time when they come to rest)?

- **A** 1.0×10^6 joules
- **B** 2.0×10^6 joules
- **C** 4.0×10^2 joules
- **D** 1.6×10^3 joules
- **E** There is no loss in potential energy.

31 In view of the information given in Questions 29 and 30, which of the following best expresses the average force of resistance exerted by the ground on the pile and the pile driver?

- **A** 6.0×10^4 newtons
- **B** 8.0×10^5 newtons
- **C** 8.0×10^3 newtons
- **D** 6.0×10^5 newtons
- **E** 1.2×10^4 newtons

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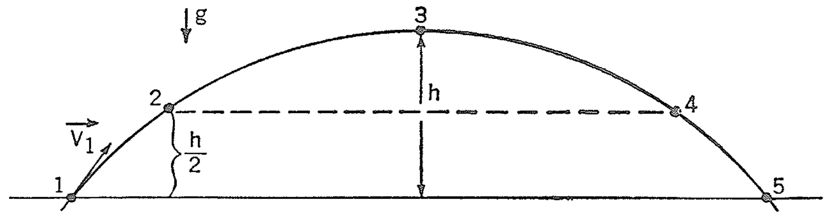
Questions **32-35** relate to the following diagram and information:



The above diagram represents the path of a projectile of mass *m* moving in a constant gravitational field without friction. It is fired, with an initial velocity $\vec{v_1}$ from point *1* along the path as shown. The maximum height attained is *h*. Potential energy is to be taken as 0 at position *1*.

32 The *total* energy of the projectile at point *3* is

- **A** $\frac{1}{2}mgh$
- **B** mgh
- **C** $\frac{1}{2}mv_1^2$
- **D** $\frac{1}{2}mv_1^2 + mgh$
- **E** $\frac{1}{2}mv_1^2 - mgh$

33 The kinetic energy of the projectile at point *3* is

- **A** $\frac{1}{2}mgh$
- **B** mgh
- **C** $\frac{1}{2}mv_1^2$
- **D** $\frac{1}{2}mv_1^2 + mgh$
- **E** $\frac{1}{2}mv_1^2 - mgh$

34 The kinetic energy of the projectile at point *4* is

- **A** mgh
- **B** $\frac{1}{2}mv_1^2$
- **C** $\frac{1}{2}mv_1^2 - mgh$
- **D** $\frac{1}{2}mv_1^2 - \frac{1}{2}mgh$
- **E** $\frac{1}{2}mv_1^2 + \frac{1}{2}mgh$

35 The horizontal component of velocity at point *1* is

- **A** v_1
- **B** $\sqrt{2}v_1$
- **C** $\sqrt{2gh}$
- **D** $\sqrt{v_1^2 - 2gh}$
- **E** $\sqrt{v_1^2 + 2gh}$

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

APPENDIX D

P.S.S.C. - TEACHER OPINIONNAIRE

P.S.S.C. - TEACHER OPINIONNAIRE

INSTRUCTIONS:

Kindly indicate your position on the following statements by circling the appropriate letter in the right hand margin as follows:

a. I agree with the statement.

b. I am inclined to agree (with reservations).

c. I cannot say (have no feeling one way or another) (the evidence is insufficient)

d. I am inclined to disagree (disagree with reservations)

e. I disagree with the statement.

STATEMENTS:

	Agree	Agr. w. reserv.	Cannot say	Disagr. w. reserv.	Disagree
1. Students seem to better understand concepts and relationships they have discovered for themselves.	a	b	c	d	e
2. The films generally produce a reaction with the students that the experimental situation has been "faked".	a	b	c	d	e
3. Most students of P.S.S.C. develop a good understanding of the natural world in which they live.	a	b	c	d	e
4. Solving problems from basic principles is not realistic because of its large consumption of time.	a	b	c	d	e
5. Laboratory materials are too "home-made" looking.	a	b	c	d	e
6. P.S.S.C. could probably be successfully taught to students of the General course.	a	b	c	d	e
7. The P.S.S.C. course is undesirable for university preparation because most technological aspects of physics are omitted.	a	b	c	d	e
8. Teachers can furnish reinforcement exercises if they are required.	a	b	c	d	e
9. The use of the films helps to speed up the teaching of the course.	a	b	c	d	e

P.S.S.C. - TEACHER OPINIONNAIRE

	Agree	Agr. W. reserv.	Cannot say	Disagr. W. reserv.	Disagree
10. The approach through analysis of graphs is too subtle for most students in the course.	a	b	c	d	e
11. P.S.S.C. seems to eliminate any advantage that was held by boys studying traditional physics over girls in the same course.	a	b	c	d	e
12. The data obtained or the measurements given in the films are confusing to most students who are attempting to understand a new concept.	a	b	c	d	e
13. An effort should be made to provide "type problems" within the course.	a	b	c	d	e
14. Paper-backs such as the Science Study Series provide a valuable resource for "further reading".	a	b	c	d	e
15. Most films should be further edited to reduce their running time.	a	b	c	d	e
16. P.S.S.C. gives students a better idea of what physicists do than does traditional physics.	a	b	c	d	e
17. The H.D.L. exercises in most cases do not present an interesting challenge to the students.	a	b	c	d	e
18. Experiments in which the correct result is known are of greater benefit to students than those in which the relationships or results are unknown when the experiment is performed.	a	b	c	d	e
19. P.S.S.C. offers little opportunity for classroom discussion.	a	b	c	d	e
20. Students should be given the security of having a formula to apply in problem solving.	a	b	c	d	e
21. The mathematical concepts required by P.S.S.C. are within the comprehension of most students electing the physics option.	a	b	c	d	e
22. Students feel that the laboratory work is not scientific in nature.	a	b	c	d	e

	Agree	Agr. w. reserv.	Cannot say	Disagr. w. reserv.	Disagree
23. Most students are not sufficiently interested to want to read outside the course of study.	a	b	c	d	e
24. The efficient and effective teaching of the course requires the presentation of most of the films.	a	b	c	d	e
25. P.S.S.C. develops in most students a good comprehension of some of the major concepts of Physics.	a	b	c	d	e
26. Laboratory materials are too crude to enable the students to get the required data.	a	b	c	d	e
27. Viewing the films gives most students a greater depth and understanding of the subject.	a	b	c	d	e
28. P.S.S.C. is more enjoyable to teach than other "traditional" physics courses.	a	b	c	d	e
29. Laboratory time would be better spent developing more sophisticated methods of problem solving.	a	b	c	d	e
30. The P.S.S.C. text lacks interest.	a	b	c	d	e