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The Development of a Modular-Flexible Schedule Model and Its Utilization in Building a New Secondary School Physics Curriculum

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THE DEVELOPMENT OF A MODULAR-FLEXIBLE SCHEDULE MODEL AND ITS UTILIZATION IN BUILDING A NEW SECONDARY SCHOOL PHYSICS CURRICULUM

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ABSTRACT

Problem

It was the primary purpose of this study to develop a secondary school physics curriculum guide for use within a modular-flexible schedule framework. A secondary aspect was to design a model modular-flexible schedule specifically for physics instruction.

Procedure

Information has been obtained through the direct visitation of seventeen schools in the Minneapolis-St. Paul and suburban areas which were using a modular-flexible scheduled program. A comprehensive study has been made of the physics curricula used in each school to determine its relative effectiveness within a modular-flexible framework.

Interrogation of administrators, staff members and curriculum specialists was employed to ascertain operational procedures.

Faculty members and students were questioned about the strengths and weaknesses experienced during the actual operation of the present curriculum within a modular-flexible schedule.

Summary

A physics curriculum especially designed to accent the benefits that accrue from a modular-flexible schedule has not been produced prior to this effort. The guide produced herein effectively reflects the basic philosophies of the three principal approaches to the study of physics. Modular-flexible scheduling and the "new-design" of the curriculum complement one another and enhance learning.

CHAPTER I

FORMULATION AND DEFINITION OF THE PROBLEM

Introduction

Mankind is now in the greatest period of change that the world has ever known. One sees a new kind of life pulsating within continents.[1] Douglass has said that men of the commercial world are trying to make the most of it; theologians are tantalized by it; philosophers reflect upon it; and educators are perplexed by it, yet must contend with it. No sphere has immunity to this contagion of change. One is conscious of accelerated developments in technology, of the "explosion" of knowledge, and the surge in the number of college-bound students.[2]

From the preceding paragraph, two observations can be made: (1) "The ills" perceived in this era of change "from which we are suffering have had their seat in the very foundations of human thought." (2) ". . . today something is happening to the whole structure of human

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[1]Pierre Teilhard de Chardin, Building the Earth (Wilkes-Barre, Pennsylvania: Dimension Books, 1965), p. 19.

[2]Harl R. Douglass, Trends and Issues in Secondary Education (New York: The Center for Applied Research in Education, Inc., 1962), pp. 3-10.

consciousness. A fresh kind of life is starting."[3] A graphic conclusion to these observations is that educators have a responsibility to place education with all its dimensions and implications in its proper place. Hence, educators envision alterations as well as marked changes in the present traditional means, as they search for realistic goals and objectives that are in tune with contemporary times.

> For better or for worse, the world today is committed to change: radical wrenching, erosive of both traditions and old values. Its inheritors have grown up with rapid change, are better prepared to accommodate it than any in history, indeed embrace change as a virtue in itself. With this skeptical yet humanistic outlook, his disdain for fanaticism and his scorn for the spurious, the Man of the Year suggests that he will infuse the future with a sense of morality, a transcendent and contemporary ethic that could infinitely enrich the "empty society." If he succeeds (and he is prepared to), the Man of the Year will be a man indeed--and have a great deal of fun in the process.[4]

Such a man must face and solve many complex educational problems. One of these is relating curriculum and scheduling so that the educational product will be enhanced.

Statement of the Problem

It was the purpose of this study (1) to examine the basic tenets of modular-flexible scheduling; (2) to structure a particular schedule for secondary school physics; and (3) to incorporate and adapt according to

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[3]Teilhard de Chardin, Building the Earth, p. 19.

[4]"The Man of the Year," Time, LXXXIX (January 6, 1967), pp. 22-23.

the needs of students and teachers traditional, PSSC, and Harvard Project materials into a curriculum for a modular-flexible scheduling system.

Four developmental phases which required extensive consideration were: (1) the development of an understanding of modular-flexible scheduling with a progression from a general philosophy to the specific schedule advocated by the writer; (2) the development from basic source materials of that curricular content most relevant to the student; (3) the development of methods of instruction most productive for student learning; and (4) the development of time blocks (modules) for each unit studied by the student.

Importance of the Study

Modular-flexible scheduling as a framework within which better instruction and relevant learning may take place has afforded educators the challenge to develop curriculum materials for such a schedule. Information about the impact on student learning when materials are presented within this framework has been meager.

In the Minneapolis-St. Paul and suburban areas where this study was centered, the schools viewed modular-flexible scheduling in a multiplicity of ways. For example, it was discernible that independent study varied from as little as 15 to 20 per cent to as much as 65 to 75 per cent of the students' scheduled time.

Modular-flexible scheduled schools have assumed that students will learn more. However, scheduling in itself does not increase learning. It can only promote (or deter) the curriculum development which facilitates the educational process.

Several questions need to be answered. Under what conditions does learning increase qualitatively and/or quantitatively? Are students capable of directing their programs with less adult supervision? What favorable attitudes toward learning are fostered by modular-flexible scheduling? What degree of independence can be permitted during "independent study"? What function does the teacher have during large group instruction, laboratory experiences, small group discussion, and independent study? What facilities are needed? Does the "open" laboratory increase injury risk, equipment loss, and breakage? Are effective student-teacher relationships weakened? Does discipline break down? What modes of instruction are basic to flexible scheduling? Does the effort eclipse the teaching-learning result?

Educators, confronted with such questions, have become aware that learning increases when co-development of the schedule and the curriculum occurs. Such development accents the positive values of both phases. A co-developed curriculum-schedule has been produced by the writer.

Method of Research

Modular-flexible-scheduled programs of seventeen schools were studied, and the students, teachers and administrators were interrogated to determine the strengths and weaknesses of each program. Physics instructors designated curriculum modifications created for the special requirements of modular-flexible schedules. Resource centers and curriculum libraries, where present, were employed. The libraries of the College of St. Thomas in St. Paul and of the Universities of Minnesota and North Dakota were utilized.

Need and Purpose

The percentage of high school physics students has been dropping almost continuously since the 1890's, while the percentages of biology, chemistry, and mathematics students have remained the same or have shown gains. A re-organized physics curriculum such as the curriculum guide which was developed to complement and to be enhanced by a modular-flexible schedule may help to check the decline.

The co-development technique proposed and the physics curriculum developed have interested the Minnesota State Department of Education.

Limitations of the Study

Modular-flexible schedule longevity in the schools studied varied from several months to four years' duration. Therefore, effective evaluations and comparisons were made difficult due to the newness of the programs.

The scope of the study was limited to physics curriculum development for a modular-flexible schedule.

The significance of this study depends upon understanding of (1) student needs in secondary school physics; (2) techniques of curriculum development; and (3) modular-flexible scheduling.

Definition of Terms Used in the Study

The terminology used in modular-flexible scheduling was first introduced about ten years ago, and workable modular-flexible programs are even more recent. Consequently, the definitions of terms have not been fixed.

Module, small group, large group, laboratory, independent study, team-teaching, team-learning, flexibility, etc., are integral parts of the vocabulary for those involved in flexible scheduling. Some of the definitions seem to be self-evident but great flexibilities exist. The meanings of four terms (small group, large group, laboratory experience, independent study) will be related in depth later; and, therefore, only brief explanations of these have been given in this section. Terms are defined to the degree of relevancy necessary for this study.

Module. A module is a block of time which can be used to build class periods of varying lengths. If a school uses twenty-minute modules, class periods must be built on multiples of twenty. If twenty-minute modules are structured, a teacher who desires to use thirty minutes for a particular lecture to a large group would not be free to do so. This larger, multiple module has been called a "class-mod" or a "period-mod."

"A schedule-module is that period of time during which the master schedule does not repeat itself. For example, in conventional schedules the schedule-module is one day."[5] This time schedule would be repeated the following day. The structure of a conventional schedule-module might have English III scheduled for the first 55-minute period-mod; mathematics III for the second; world problems for the third; lunch for the fourth; German III for the fifth; chemistry for the sixth; and study for the seventh period-mod. This is not the case with schools organized on the modular-flexible scheme. Such schools commonly have a schedule-module that extends for one week. Modular-flexible scheduling does not usually allow each student's schedule to repeat itself daily, however, part of his schedule may be repeated. For example, those modules assigned to lunch may occur regularly, but, even here, variability may extend over several periods. Chances are manifold that a student will not have the same subject period-mods each day, nor will his classes meet for the same number of period-mods at each meeting.

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[5] J. Lloyd Trump and Dorsey Boynham, Guide to Better Schools--Focus on Change (Chicago: Rand-McNally Company, 1961), p. 21.

Team-teaching. "A teaching-team consists of from three to seven or more teachers jointly responsible for the instruction of 75-225 or more pupils in one or more age groups or grade levels."[6] The team members should hold regular meetings to set overall aims for the subject area content, as well as the specific objectives to meet the ability and interest levels of the student groups; to make decisions pertaining to individual teacher talents so that the more talented, in one particular aspect of the subject matter, has responsibility for that area; and finally, to evaluate both the progress of the teaching-team's endeavors and the student. A school which has team-teaching programs "emphasizes the team, rather than the individual teacher in the planning, teaching and evaluating cycle."[7]

Team-learning. This refers to a student-student relationship where the better students work with those not-so-strong academically. Laboratory experiments and some tests are scored by the team rather than by the individual teacher. The student-pairs are expected to study together during part of their independent study time. Team-learning has demonstrated that students learn readily from their peers.

Flexibility. Any variation from the normal time schedule demonstrates flexibility. This term has been used for years in connection with

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[6]Medill Bair and Richard G. Woodward, Team Teaching in Action (Boston: Houghton Mifflin Company, 1964), p. 28.

[7]Ibid., pp. 29-31.

traditional scheduling changes. Shifting class periods to meet any unusual situation represents flexibility. The broad term should not be confused with modular-flexible which has more restricted limits.

Modular-flexible scheduling. This is a new design in scheduling where class periods are constructed on a pre-determined "module," or period of time basis; and which provides "flexible arrangements which consider not only pupil differences, but consider those unique talents and specialized competences of teachers and differences in the subject fields as well."[8]

Large group. This type of instruction "refers to teacher-planned presentations either provided by the teacher himself, or by the use of a guest, a film, or a recording."[9]

Small group. This is a group that usually would not exceed 15 to 20 students. Through group discussions pupils use and reinforce the knowledge they gain in large groups and independent study.

Laboratory experiences. These refer to the actual use of physical facilities for conducting experiments, but they also include research and project work.

Independent study. Learning under this type of study is dependent largely upon the students' initiative and interests.

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[8] Trump and Boynham, Guide to Better Schools, p. 5.

[9] J. Lloyd Trump and Delmas F. Miller, Secondary School Curriculum Planning (Boston: Allyn and Bacon, Inc., 1968), p. 274.

Background of the Problem

An educator should have a philosophy that leads rather than directs, if he is to meet successfully the demands of the "modern" school.

A Philosophy of Education

Regardless of what the school of educational philosophy may proffer, all schools of educational thought in America have at their core the concept of child-centeredness.

Nearly every educational philosophy embodies the aims and objectives known as the Seven Cardinal Principles of Education. Modes of realization vary, but as Scott wrote,

> Education should pave the way to brotherly association with other peoples, so that genuine unity and peace on earth may be promoted. For a true education aims at the formation of the human person with respect to his ultimate goal, and . . . to the good of those societies of which . . . he is a member, and in whose responsibilities . . . he will share.[10]

This basic aim should remain constant as educators attempt "to provide for each child--girl and boy, rich and poor, native and alien, gifted and retarded--a continuing education through the twelfth grade."[11]

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[10]Walter M. Scott, S. J., ed., "Declaration on Christian Education," The Documents of Vatican II (New York: Guild Press, 1966), p. 639.

[11]Morris Gall and William V. Hicks, Modern Secondary Education (New York: American Book Company, 1964), p. 1.

In the attempt to provide the subject matter content for the attainment of the Seven Cardinal Principles, educators have been confined by structure. Modular-flexible scheduling has been designed to combat this limitation.

A Philosophy of Flexible Scheduling

Educational research has helped to negate some concepts which encumber the general educational system. These are (1) that all teachers are alike; (2) that a pre-determined period length can serve many purposes effectively and efficiently; (3) that a class size of thirty students is equally appropriate for the many different kinds of instruction; (4) that the self-contained classroom with one teacher is equally appropriate for a wide variety of learning experiences; (5) that all learners in a group should study the same course content and should learn at the prescribed rate, implying similar interest, motivation, and innate ability; (6) that students should be scheduled for at least two hundred minutes per week in all courses; and (7) that students will not learn unless they are taught in classrooms by teachers.[12]

"Administrators and teachers confused equality of opportunity and democracy with uniformity,"[13] and they constituted rigid and equitable

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[12] E. R. Howard, "Flexible Scheduling," North Central Association Quarterly, XL (Fall, 1965), p. 208.

[13] J. Lloyd Trump, "Flexible Scheduling: Fad or Fundamental," Music Educators' Journal, LII (November, 1965), p. 61.

scheduling. It is apparent that the "right conventional schedule constitutes one of the most formidable impediments to progress for schools desiring to encourage independent learning."[14] Delimiting factors in the traditional schedule have stimulated research and experimentation in the area of scheduling. Many educators believe that an immediate change should take place in the conventional schedule, and students indicate the want for opportunities to develop individual responsibility and the skills of independent study. The typical school system does the opposite as it chalks each step of the student's program from his entrance upon the "educational stage."[15]

Independent study may help in the development of responsible individuals, but the values of independent study do not end with the teaching-learning of responsibility. Creativity doors are opened by such study. Modular-flexible scheduling is the framework within which these learning situations can take place.

Contemporary students must become aware of the relevance of communicative skills. They should learn to think clearly and critically. "Free" discussion during small group activities produces a needed sensitivity to local, state, national, and world problems.

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[14]Howard, "Flexible Scheduling," p. 208.

[15]Trump and Boynham, Guide to Better Schools, p. 5.

> Discussion in today's schools is often limited to a few remarks between the teacher and one pupil. Really effective discussion of important content develops best in the small group of no more than twenty persons, a setting logistically difficult to achieve in today's schools.[16]

> Appreciation of difference in race, religion, social class, economic attitudes and national origins need to be learned. Learning to live with these differences with mutual understanding without abandoning one's heritage or denying equal consideration to others is a major objective of the general education program.[17]

With traditional schedules and teaching methods, it has been possible to arrange for students to study about a subject; however, no academic skill is acquired by studying about, listening about, or writing about it. The student must participate in a real situation, if he is to become steeped in desired attitudes. Effective relationships are an outgrowth of respect for "innate dignity of other humans and an understanding of the varieties of thought and behavior that cloak that dignity."[18] Through flexibility in scheduling, a greater possibility for effective relationships ensues.

There is no way of ascertaining what the ultimate in flexible scheduling will be, but the

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[16] Ibid., p. 6.

[17] Scott, The Documents of Vatican II, p. 639.

[18] John S. Brubacher, Modern Philosophies of Education (3rd ed.; New York: McGraw-Hill Book Company, 1962), p. 253.

goal necessarily is to return to teachers and students as much freedom, with responsibility, as is efficiently effective in the use of time, space, numbers (in the group), and content for instruction.[19]

A concise philosophy for modular-flexible scheduling is found in the following quotation:

> The central issue of our day is human freedom, and the crux of freedom is the right of the individual choice. Freedom of action has necessary limits, but freedom of expression must not be denied even to those on the left or on the right who are the enemies to liberty.[20]

History of the Problem

In education, there has long been concern for and effort directed toward child-centered curricula. Rousseau, a naturalist, had as an aim the development of the natural powers of the individual. He wrote ". . . excite in children a desire to learn. Give a child this desire, and do as you will . . . any method will then be sufficient."[21] Froebel proclaimed that the creative self-development of the individual was of foremost importance. His activity curriculum utilized "free play" as an educational tool. He said,

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[19] Howard, "Flexible Scheduling," pp. 208-09.

[20] Trump, "Flexible Scheduling," p. 139.

[21] Robert Ulich, ed., Three Thousand Years of Educational Wisdom (Cambridge, Mass.: Harvard University Press, 1954), p. 405.

> To stir up, to animate, to awaken, and to strengthen, the pleasure and power of the human being to labour uninterruptedly at his own education, has become and always remained the fundamental principle and aim of my educational work.[22]

John Dewey wrote "All education proceeds by the participation of the individual in the social consciousness of the race."[23]

Traditionally, the teacher has been given the task of relating information to the student. He has been a "well" of factual information. The student's role was passive; to accept the ideas and habits imposed upon him. Student responsibility apparently ceased with the replay of mentally taped material. In contrast, Saylor and Alexander stated that "Our kind of society calls for the maximum development of individual potentialities at all levels."[24] It is fortunate that the means to educate everyone to the level of his ability and the means to provide excellence in education are not incompatible.[25]

Educators have long sought means and methods to individualize instruction. At first, the process of individualization was aimed at making better citizens and stronger societies. More recently, educators

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[22] Ibid., p. 525.

[23] Ibid., p. 629.

[24] J. Galen Saylor and William M. Alexander, Curriculum Planning (Chicago: Holt, Rinehart and Winston, Inc., 1966), p. 369.

[25] Rockefeller Brothers' Fund, "The Pursuit of Excellence: Education and the Future of America," in Panel Report V of the Special Studies Project (New York: Doubleday and Company, Inc., 1958), p. 22.

have begun to emphasize the individual and the worth placed on "self." Modern curriculum materials have been directed toward the discovery, through an inductive approach, of the meaning of subject-matter to that "self." Individualized instruction has been a sought aim, even as traditional, rigid schedules have made group education an accepted reality.

In the search for individualization, educators have tried many departures. Heretofore, no departure has been as radical a change as that of flexible-modular scheduling. Professor Dwight W. Allen, when speaking to a group of educators, said:

> Achievement, not time spent in class should be the criterion for educational progress. Emphasis should be on the continuous development of responsibility rather than on a demanded metamorphosis at the time of college entrance or vocational employment. The only way educators can achieve continuous development of responsibility among their students is to provide for new levels of individualization within the school program.[26]

Modular-flexible scheduling can do this for the modern school.

Trump and Miller wrote:

> Independent study may be an individual activity or it may involve two or more pupils working together. A group of pupils with similar needs for remedial work may work in a specially equipped laboratory, or an advanced group with special interests may cooperate in a project. In any case, the emphasis remains on

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[26]Stanford University, School of Education Conference, "Individualized Instruction," California, 1966. (Mimeographed.)

> the individual, who has been placed in a learning situation where he may succeed and contribute to others as well as to his own personal development.[27]

Albert Oliver contends:

> Ultimately the focus of attention must go from broad generalizations about the activities of a class down to the individuals in it. In actual practice the reverse attack often is more effective, that is, concern about an individual leads to inquiry about others in this class, this school, this society.[28]

Good teachers have long recognized that each child is unique, and that individual differences in children influence their abilities to learn; but such recognition has done little to correct the lack of individualized instruction. Usually, the attempt to solve the dilemma has been through the addition of more electives to the school program. This has not worked. As stated by Thorton and Wright:

> As the full extent of individual differences among students of the same age or grade level was understood, it became apparent that mere proliferation of elective courses would not provide the best education for all youth of high school age.[29]

Historically, the problem has been of long duration. This study emphasized the need for radical departure from the traditional. Three apparent needs were:

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[27]Trump and Miller, Secondary School Curriculum Planning, p. 265.

[28]Albert I. Oliver, Curriculum Improvement (New York: Dodd, Mead and Company, 1965), p. 157.

[29]James W. Thorton, Jr. and John R. Wright, eds., Secondary School Curriculum (Columbus, Ohio: Charles E. Merrill Books, Inc., 1963), p. 90.

1. To create a schedule that would permit a greater proportion of the school day to be used for individualized instruction (independent study);

2. To design a curriculum from selected materials that would make physics more useful and interesting to the student; and

3. To fuse the new mode of scheduling with the specifically designed curriculum.

CHAPTER II

SURVEY OF RELATED LITERATURE

American society had not yet been "alarmed" in 1956 by the Russian achievement in space exploration, although information had filtered through about the coming of Sputnik. The Russian success in 1958 served as a catalytic agent accelerating development already begun in the fields of science and mathematics. The low level of instruction prevalent in secondary school physics had been noted, but the imminence of Sputnik crystallized concern and directed efforts toward upgrading physics materials and modes of instruction.

Since 1956, three major pedagogical influences have been felt in the field of secondary physics. In the fall of 1956, the Physical Science Study Committee was born. In 1960, Professor R. V. Oakford, an industrial engineer, developed a computer scheduling system, and, in 1964, Harvard Project Physics piloted its curriculum.

Literature Related to the Physical Science Study Committee (PSSC)

The Physical Science Study Committee was born when Professor Jerrold R. Zacharias, the Department of Physics of the Massachusetts

Institute of Technology, assembled some 60 leaders in physics, education, apparatus design, writing, art, and other specialities to pool their knowledge and experience and produce a pilot model of the PSSC physics course.

The Committee was funded by a grant from the National Science Foundation, and later by contributions from the Ford Foundation and the Alfred P. Sloan Foundation.

The literature reveals conflicting opinions regarding the value of PSSC. Evaluation has been difficult because PSSC has a continuous program of review and change. An extensive attempt at evaluation of the program has been done by Frederick L. Ferris, Jr. His study was completed when PSSC was still in its formative stage. The study included the following questions:

1. Was the group of students in the PSSC program during 1958-59 representative of the aptitude level for which the course was designed?
2. Was the course generally appropriate to the ability range of students for which the course was designed?
3. Was the course, as many critics had predicted, hopelessly beyond the capacity of physics students in the lower aptitude ranges?[1]

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[1]Frederick L. Ferris, Jr., "An Achievement Test Report," The Science Teacher, XXVI (December, 1959), pp. 574-81.

Ferris' results indicated that PSSC physics was designed for the typical United States high school physics student. However, most United States physics students are from the upper twenty-five per cent of high school students when scaled according to ability and scholastic aptitude.

Dr. Gilbert Finlay surveyed physics teachers' opinions of PSSC. He summarized his findings in three succinct statements which demonstrate the wide spectrum of teacher opinion:

> 1. The course is over the heads of average and poor students.
> 2. The students rated the course as generally more difficult than average . . . since we used the course for all physics classes and no grouping was done, the level of understanding varied greatly.
> 3. The general difference between the work done this year and that of other years was that poor students got a little more this year and good students got a great deal more.[2]

The literature revealed that more teachers opposed the program than supported it. Oscar L. Brauer summed up the negative opinion:

> In the first place it is not designed for the general high school physics student, although they (PSSC) pretend that it is . . . poorer students are no better off than they would have been had they taken no physics at all . . .[3]

In 1957-58, eight schools and 300 students tried the PSSC materials. Then, in 1958-59, nearly 300 schools and 12,500 students

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[2]Gilbert Finlay, "Summary of Judgments Made by Teachers," The Science Teacher, XXVI (December, 1959), pp. 579-81.

[3]Oscar L. Brauer, "Something Dangerously New in Physics Teaching," Science Education, IIIL (October, 1963), pp. 365-71.

used the course, and in 1959-60, almost 600 schools and 25,000 students participated. Meanwhile, the process of evaluation had accented the dissenting opinion, and PSSC has lost much of its impact.

Experience with teaching PSSC demonstrated that it was a course designed by specialists for specialists. Student ability and interest were not given prime consideration. There are, however, many valuable facets contained within the PSSC course. In the humanistic curriculum guide prepared by the author selection of materials from PSSC gave primary importance to student ability and interest.

Literature Related to Curriculum and Scheduling

Curriculum planners have developed "new" materials and radically changed the approach used to implement their adoption, but each effort has been stymied by strict adherence to traditional time schedules. Flexible scheduling has been attempted by educators, but real flexibility became increasingly difficult as student populations increased. Traditional scheduling procedures too were cumbersome and unwieldy with large numbers, because they relied mostly on manual procedures.

In the spring of 1960 the Ford Foundation and its Fund for the Advancement of Education financed the Stanford Computer-based High School Flexible Scheduling and Curriculum Study. Professor R. V. Oakford, computer scientist and engineer, developed the process which later became known as the Stanford School Scheduling System (SSSS).

Computer scheduling success meant that manual scheduling was no longer a chief restraint to curriculum experimentation.[4]

Recent literature related that many types of experimental schedule modifications were in operation. Traditional period schedules were being changed to period-mods of fifteen, eighteen, twenty, twenty-four, twenty-eight, thirty, etc., minutes. Time allocated to particular courses varied from one day to the next, and total time given to a subject has become aligned with the level of difficulty. Modular-flexible scheduled programs were allowing things to be different.

Traditional schedules used team-teaching, team-learning, laboratory experiences, and, although less commonly, large group instruction; while project work permitted a kind of independent study, and panel discussions functioned somewhat like small groups. However, it was not until computerized scheduling that the full potential of the last two types began to be realized.

Independent study during the school day was utilized as the thread that gave continuity to instruction. This phase of instruction was regarded as essential by curriculum planners, if modular-flexible scheduled programs were to be promoted. Schedule modifications should

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[4]Stanford University, School of Education Conference, "Flexible Scheduling: A Reality," California, 1966, pp. 1-2. (Mimeographed.)

be considered part of curriculum development.[5] A condensation of the literature pertaining to independent study may be expressed as "time for the student to be creative."

The second vital phase of instruction utilized within modular-flexible schedules was the small group, the least clearly understood of the four basic phases. DeLoy stressed that educators think of the small group in terms of numbers or size alone, neglecting the difference in teaching techniques and mode of learning involved. The small group provided a powerful resource for learning that focused on the behavior of the group members as well as the teacher. A new role was required of all participants. Communication was freer, while anxiety was minimized. Small groups varied in size, but they should be composed of five to twenty members.[6]

Glatthorn emphasized the importance of the small group when he stated:

> Let me begin by stating flatly that the small group is one of the most important educational innovations to be discussed at this conference. We could survive without the large group. We could manage without the complexities of the flexible schedule. But without the small group we would inevitably fail in our educational task. The reason is simple: it is only through

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[5]Dwight W. Allen and R. B. Moore, "Nothing Ventured, Nothing Gained," California Journal of Secondary Education, XXXV (February, 1960), pp. 91-93.

[6]Stanford University, School of Education Conference, "Small Group Instruction: A New Challenge," California, 1966, pp. 1-2. (Mimeographed.)

> the small group that we can multiply the opportunities for pupil-teacher interaction and very significant kinds of learning take place through such interaction.[7]

The small group is such a vital component of learning that it must be an often scheduled activity. However, it could not function adequately and smoothly without the framework of modular-flexible scheduling. In this manner, the literature often has stressed that scheduling and curriculum planning go together. A change in the scheduling process should effect a change in the area of curriculum.[8]

Thorton and Wright have claimed that successful scheduling demands an appraisal of student performance. They have said also that student performance includes achievement and progress toward important instructional goals or objectives.[9] The scheduling process should not be directed toward increasing the performance of students. Educators who attended a Stanford University conference on small group instruction believe that independent study and small group instruction afford the personal contact necessary for adequate appraisal of the individual student's worth. They said that scheduling of these two phases demands

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[7]Allan A. Glatthorn, "Learning in the Small Group," Institute for Development of Educational Activities, Melbourne, Florida, 1966, pp. 3-5. (Mimeographed.)

[8]Saylor and Alexander, Curriculum Planning, pp. 518-19.

[9]James W. Thorton, Jr. and John R. Wright, Secondary School Curriculum Development (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967), p. 233.

a site for personal and group study, such as a resource center which should be established within the department.[10]

"Who should be involved in the planning of educational facilities? The simplest answer is everyone who can make a contribution to the planning process."[11] It was felt that the entire school community should be involved, but that the major task becomes one for the staff. Time for curriculum improvement has been a major concern of school administrators, and modular-flexible scheduling could enable them to schedule within the school day teacher activities to accomplish the task.

Literature Related to the Harvard Project Physics

Harvard Project Physics began in 1964 and has grown until, according to the Project Newsbrief (March 1, 1969), it then enrolled a total of 8,999 high school students in the course. In addition, there were 1,100 college students in 10 colleges, for a grand total of 10,099 students who were testing and evaluating the Project.[12]

A review of the literature pertaining to Harvard Project Physics had strict limitations, because: (1) the course materials had not been made

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[10]Stanford University, "Individualized Instruction," pp. 2-3.

[11]Ross L. Neagley and N. Dean Evans, Handbook for Effective Curriculum Development (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967), p. 253.

[12]Harvard University, Harvard Project Physics, "Teacher's Newsbrief," Cambridge, Massachusetts, March 1, 1969, p. 2. (Mimeographed.)

available commercially; and (2) printed matter that was available reflected strong bias because its origin was the Project.

Proponents of the Harvard Project have recognized many aspects of the teaching-learning process. Holtan, writing about the Project, stated that the four most relevant objectives of the program were: (1) to create a coherent, tested course for use on a national scale alongside others that have been developed previously; but it was to be a course that accentuated those aspects of physics and pedagogy which, although held to be desirable, have not been prominently incorporated into course developments in physics on the high school level; (2) to help stem the decline in proportionate enrollment in physics at the high school level--a decline which in fact has now reached into the college years; (3) to provide teachers with all the necessary teaching aids for teaching good physics in existing classroom situations; and (4) to require re-thinking some basic questions, such as the new role of the teacher and his rapport with the class, the new desire to allow greater diversity and flexibility, and the new opportunities opened up by the developing technology of education.[13]

It seemed possible that diversity and variation would become predominate characteristics of physics teaching in the schools and

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[13]Gerold Holtan, "Project Physics. A Report on Its Aims and Current Status," The Physics Teacher, V, No. 5 (May, 1967), pp. 198-211.

would permit the physics teacher to reassert his position as the chief designer of the course he teaches. Project Physics "set out to design a course that permitted and indeed encouraged variation," according to Rutherford.[14] The central core of the course was to be selected from the materials presented by PSSC, Harvard Project and the more traditional. The course was to be designed to meet the needs of boys and girls, to excite the interest, and to increase understanding of the students' physical universe. Although the laboratory technique used by Harvard Project Physics was not considered to be the discovery-oriented method, the experiments lent themselves to this instructional mode.

The review of the literature related to the major influences affecting physics course development was not meant to accentuate particular strengths and weaknesses in the PSSC, Harvard Project Physics and traditional materials. It was directed toward underscoring the lack of relevancy of single-approach materials to the physics student. Harvard Project has introduced another approach, alignment and organization for consideration, but, although the pilot stage has not been completed, rumblings of discontent have already been heard.

Physics instructors have stated that class-period structure contributed to the lack of student interest. The introduction of modular-flexible scheduling eliminated the rigid structure factor; however, no

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[14] James F. Rutherford, "Flexibility and Variety in Physics," The Physics Teacher, V, No. 5 (May, 1967), pp. 224-229.

enrollment increase ensued. This indicated that single-approach physics courses even when presented in a modular-flexible framework do not have an incentive level high enough to captivate students. A pluralistic approach which more effectively utilized learning domains might meet the need. Traditional courses have emphasized the cognitive domain, while PSSC and Harvard Project have accented the cognitive-psychomotor and affective domains, respectively.

The curriculum guide prepared as an appendix to this study contains selected materials from each of the three plans of instruction set in a modular-flexible framework. The approaches, methods and materials have been molded into the guide so that independent study and small group instruction have been maximized. The guide has sought to obtain a balance in the use of the domains of learning. Appendix A presents an outline of the learning domains so that teachers may more thoroughly understand the content, processes and outcomes for each.

There has been much conflict among those who represent the three schools of thought. A comparative study has been prepared that discusses the basic differences. The Comparison of Study Programs for Secondary Schools, Figure 1, has need for a clarification of terms. In the figure, words underlined have been defined at the base of the comparison. The definitions, in general, are those most commonly accepted in the field of education.

	Traditional	PSSC	Harvard Project
Approach	lecture--demonstration	experimental (conduct the experiment, observe and theorize)	historical (relate scientific achievement to the individual and era; past to present and theorize)
Method	deduction	induction	deduction-induction
Emphasis	textbook oriented	laboratory oriented	idea oriented
Coverage	restricted (basically a single text)	restricted in breadth (great depth in a few units)	restricted in depth (great breadth . . . a veritable raft of material)
Reinforcement of Materials	limited, lacks interrelatedness	limited, lacks interrelatedness	strongly reinforced, e.g. study Galileo then at a later date relate him to Newton
Arrangement	unitized by chapters	unitized into four major parts	unitized with many units and subunits
Learning Domain Emphasis	cognitive	psychomotor and cognitive	affective and cognitive

deduction--applies to the process by which one starts with a general principle that is accepted as true, applies it to a particular case, and arrives at a conclusion that is true if the starting principle was true.

induction--applies to the process by which one collects many particular cases, finds out by experiment what is common to all of them, and forms a general rule or principle which is probably true.

domains-- cognitive--knowledge, intellectual abilities and skills; psychomotor--manipulative, muscular, or motor abilities and skills; affective--attitudes, interests, values, and appreciations.

Fig. 1.--A Comparison of Study Programs for Secondary School Physics with Apparent Accent Points

CHAPTER III

SCHEDULING

At least seven elements indicated conflict between the traditional and the flexible schools of thought. Comparison of the two schools left no doubt that real change transpires when traditionalism has been eliminated and flexibility installed. The rigidity of traditional schedules becomes conspicuous during comparison:[1]

Element	Traditional Schedule	Flexible Schedule
Content	Assumes each course is equivalent in requirements for mastery to all others.	*Assumes requirements for mastery of content vary from course to course.
Facilities	Use is set by the schedule.	Use is sometimes determined by the needs of students.
Groups	All class groups are nearly equal in size.	Class groups differ in size depending on the instructional task.
Scheduling Unit	Each day in the week has the same order as every other day.	Each day in the week has different order.

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[1] Donald C. Manlove and David W. Beggs, III, Flexible Scheduling (Bloomington: Indiana University Press, 1965), p. 42.

Students	Students should be in class or supervised study.	Students may be in class, study, or work independently.
Teachers	All have equivalent assignments and demands on their time.	Number of classes varies from teacher to teacher and demands on time vary.
Time	Usually equal for all subjects.	Usually different for various subjects.

*Basic assumption for modular-flexible scheduling.

Note: The length of the school day is assumed to be equal in the schedules.

Modular-Flexible Scheduling

Educators have been seeking answers to the following questions: (1) What is basic to modular-flexible scheduling that makes it a desirable organization of the school day; and (2) how could it be analyzed in order to determine its functions. Complete answers to these questions have been hindered by constant change in modular-flexible programs.

An essential that should be produced by modular-flexible scheduling has been observed. Schools using it were perceiving control by teachers and administrators rather than by the system of scheduling. Schedules served the educational system rather than directing and restricting instruction. Howard wrote:

> Such a schedule must provide an adequate structure so that the school can operate efficiently. This structure must, however, be broad enough to allow teachers and students progressively more autonomy in decision-making.[2]

Autonomy has been more fully achieved under this system.

The schedule was not the only highly structured component of a school system. There were apt to be inflexible facilities, people, and curricula. Altering the schedule did not assure improvement in instruction. Proponents of modular-flexible scheduling believed significant improvement resulted only when a well-planned attack was made in all areas. However, the schedule was the one factor which encompassed all others.[3]

In the field of scheduling, educators have made bold advances. Administrators and teachers have realized that some courses demand more time and a higher percentage of contact time than others. For example, science laboratory classes need longer periods than other subject areas. Because of this "time" need, science has tended to direct scheduling. Proper utilization of the "modular concept" of flexible scheduling would not permit such direction.

Modular-flexible scheduling has organized instruction in combinations of four phases: (1) large group instruction; (2) small group discussion; (3) learning laboratory; and (4) independent study. Science

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[2]Howard, "Flexible Scheduling," p. 283.

[3]*Ibid.*, p. 284.

instructors have found all phases readily adaptable to their subject area.

Phase One: Large Group Instruction

This phase emphasizes the importance of presentation. One lecture to the large group delimits repetition, and students benefit from the freshness and enthusiasm of the instructor's "first" lecture. Prior to the live presentation, the lecturer should video-tape and critique the lesson with the other team members. Suggestions and corrections designed to improve the lesson should be made with complete freedom.

Students are given an outline at the beginning of the large group session and are expected to enlarge the outline by note-taking as the lecture is delivered.

Large group instruction has multiple values such as: (1) permits the use of the most talented team member as group lecturer; (2) allows scheduling of guest speakers, televised programs, motion pictures, and recordings with little disruption of other classes; and (3) facilitates testing.

In physics, large group instruction frequently becomes a lecture-demonstration combination utilizing students and peers as aides. Where the strict lecture method is used, student involvement is more passive. Involvement should be carefully planned. The lecturer presents material needed during small group discussions.

Phase Two: Small Group Discussion

This phase emphasizes face-to-face contact and verbal interaction between student and teacher, and student and student.

The small group has proved to be effective and efficient for the explanation of physics problems. "Analytical and exploratory discussions and group critiques demand limited numbers."[4] Group interaction provides opportunity for individual participation, if the group is small, i.e., a group of not more than twenty pupils. There is danger of group takeover by a strong personality if too few students are in the group, so the limits are usually fixed at from eight to twenty members.

In the proposed physics structure, the small group size has been set at twenty members, two of which are elected team leaders. This permits sub-units of ten students with their instructor floating between the sub-units during their operation. Team-learning may be emphasized within the sub-units and competition between the sub-units should be maximized.

The small group should be utilized when interaction is desired in the following kinds of situations:

1. Evaluating lessons and ascertaining implications for solving problems.
2. Explaining possible reasons for the action when given a

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[4] Trump and Boynham, Guide to Better Schools, p. 36.

certain set of conditions.

3. Constructing generalizations from phenomenon observed in a science demonstration.

4. Discussion of possible applications of a principle or theory.

5. Deriving generalizations from real-life situations.[5]

The length of the small group period may vary. It is not uncommon nor irregular for two or three uninterrupted twenty minute modules to be used for the small group period of instruction.[6] This phase affords an opportunity to stimulate the student and encourage independent study.

Teachers must be re-educated as to their role in small groups. The group must not be teacher-centered. The small group has been set up as a student-led unit. When a student listens to, agrees or disagrees with, and accepts or rejects another person's ideas, sensitivity to that individual, his needs and viewpoints, becomes more personal.

The skills which teachers must strive to develop in the small group instructional techniques are:

1. Accurately observing cues that reveal a student's personal learning needs.

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[5]Rowen C. Stutz and Russell G. Merrel, eds., Western States Small School Project (Denver, Colorado: State Department of Education), p. 20.

[6]Ibid.

2. Ability to induce "set" or initial inquiry by means other than dominance.

3. Ability to perceive group consensus and to initiate closure and direction.

4. Becoming a member of the group in good standing (learning to be quiet, to listen and to observe).[7]

Conversion from traditional modes to small group methods with individual involvement may be an overwhelming experience. Some teachers are unable to cope with this phase. However, students and teachers who understand the nature, purpose, and potentialities of the small group find this learning experience to be invaluable intellectually, personally, and socially.

Phase Three: Laboratory Experiences

This phase is so closely associated with independent study that many who write about flexible scheduling do not present it as a separate phase. Laboratory experience is a type of learning that has been used extensively in science instruction since it stimulates hypothesizing from observations. Observation begins the laboratory process and initiates the learning.

The teacher's role in this phase is to plan laboratory experiences

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[7] *Ibid.*, p. 21.

and serve as an important resource, while the learner explores, experiments and tests what he has learned.

Phase Four: Independent Study

This phase requires that students engage in study apart from other students and, often, independent of the supervision of the teacher. The types of work which a student may do in independent study are: drill to attain mastery of the basic skills, reading, writing, research, and working with teaching machines and other automatic instructional devices. Independent study may take place as part of laboratory instruction. "The purposes of this type of instruction are to promote independence, to provide opportunity for study of topics beyond the regular curriculum, and to permit maximum use of instructional resources."[8]

The idea of independent study is not new; but in the structure of modular-flexible scheduling, it has taken on new implications. Traditional policies were based on the assumption that students abuse free study time unless they are supervised continually. Properly ordered flexible scheduled schools have not found this to be the case.

Independent study has one unique possibility that other phases of flexible scheduling do not possess; namely, the specialized study project. The specialized study project allows a student to pursue a

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[8]Robert N. Bush and Dwight W. Allen, New Design for Secondary Education (New York: McGraw-Hill, 1964), p. 35.

particular course of study, or a particular unit of study within a course, independent of his class. The specialized study project should be an integral part of the physics course. The following steps should be carefully considered in the establishment of a "project system."

Physics Specialized Study Project

1. An explanation of the program should be made to the students by the physics instructor during a large group time unit. Application forms should be made available.
2. Completed forms should be returned to the physics instructor by those students who are interested in project work. This should be accompanied by an outline of the project to be undertaken.
3. A review of the application is then made by the faculty committee and the physics instructor. The project is likely to cross-over subject matter lines, so it should be reviewed by all involved faculty members.
4. The committee will accept or reject student applications after the review has been completed.
5. Projects accepted as special study must be discussed with all involved teachers where credit is sought. This will necessitate a student-teacher conference.
6. The project is to begin the second semester.

7. Periodic progress reports must be made by the student to all instructors involved.
8. Each project participant is required to make an oral report of not more than 1/2-1 module to the large group.
9. The finished project is evaluated by all teachers where credit was to be given.

The Project

1. The project should be in some area that is of interest to the participant.
2. The project should be of such a nature that in pursuing it the student will make use of knowledge gained and skills developed in all or at least several subject areas.
3. The project should be such that it can be completed in three months.
4. The project should be in an area in which the physics instructor and/or related science personnel are competent.
5. The project should be such that a tangible product can be exhibited upon completion.

Each school should establish its own set of purposes and qualifications for participation. Rules should be set that will govern selection of participants and determine the amount of credit to be given the student. If this is done properly, the specialized study project becomes an outstanding motivational learning tool.

Physics teachers should incorporate all phases of modular-flexible scheduling in their courses. However, in physics, independent study, laboratory work, and small group instruction are the student's program. An effective schedule may readily allocate ninety per cent of a student's time to these three phases.

Figure 2 depicts a Structural Design Model that visualizes the four phases of instruction. The large group for the physics program

Presentation (10%) Lecture-Demonstration (not more than 10% of the student's scheduled time	Scheduled Research	Unscheduled Tutorial
Doing (20%) Experimentation Laboratory Group	Study	Teacher- Student (1-1)
Discussion (30%) Small Group 30% (plus)	Directed Study	Independent Study (30-40%)

Fig. 2.--Structural Design Model

involved approximately forty students. (There was no real limit to the number that could be handled in this phase.) It was believed that the majority of schools in the area would not go beyond this enrollment, so it was selected as functionally representative. Most schools had only one physics teacher, and, sometimes, was only a part-time instructor. In such cases, he would find that flexibility afforded advantages by permitting completion of laboratory experiments before an incoming class in another subject. The "open" laboratory might have to be limited if the school had a multi-purpose laboratory which was for all the sciences. Multi-purpose laboratories were common in small schools. Figure 2 with the seven basic divisions of study can be adapted to multi-purpose conditions with relative ease. This figure indicates that independent study (I.S.) has been recognized as the core of the model. At least thirty per cent of the student's school time should be allocated to this phase. Personalized instruction, a tutorial period with one to one contact for the teacher and student, took place during the unscheduled time. The model has been designed to aid scheduling and programming of students.

In physics, a ten, twenty, thirty, and forty per cent division of time allows effective and efficient class programming.

CHAPTER IV

PRELIMINARY PROCEDURES FOR THE ADOPTION OF MODULAR-FLEXIBLE SCHEDULING

The Work of the School Certified Personnel

General Procedures

The attitude of the staff must be one that expects a modular-flexible schedule to extend student learning opportunities. The staff should be cognizant of the number of variables which make the success of the program unpredictable.

Modular scheduling should be structured for each particular school. There are three requisites that demand primary consideration:

1. The staff and administration must be positively enthusiastic.
2. The facilities must be adequate or money should be available to make them adequate.
3. The student body must be determined capable of handling the independent study time in an acceptable manner.

Determination of these requisites should be the major staff responsibility. Success is dependent upon the degree of positive acceptance and resolution of the listed points. Since flexibility is a fundamental deviation from the conventional structure in which teachers are steeped, it is the responsibility of all those who work in a school system to become familiar with the nature of modular-flexible scheduling.

The school personnel must carefully chart all resources. Thorough knowledge of the personnel, curriculum, classroom and laboratory facilities, size, nature, and intellectual strength of the student body, must be obtained. This demands total involvement of the school community in the planning.

Specific Procedures

The study revealed some specifications which administrators and teachers must agree upon before the adoption of modular-flexible scheduling can take place. Specifications include:

1. The basic building blocks (modules) for construction of a modular-flexible schedule must be determined. If district policy does not designate the module time length, then the certified personnel must set the length.
2. The number of students (minimal and maximal) that are to comprise the small group units.
3. The number of students comprising each large group and available facilities for large group instruction.

4. Determination of the school day and the number of modules within that day. (The plan presented proposed the use of twenty modules each of twenty minutes duration.)

5. Establishing the course cycle. This may repeat itself every week, every two weeks, or as infrequently as every semester; however, the weekly cycle appears most workable and valuable.

6. Determination by the teaching-team of:

   a. the number of modules per week to be used for course instruction.

   b. the number of modules to be used each day for course instruction.

      (1) for large group instruction.

      (2) for small group instruction.

      (3) for laboratory experiences.

      (4) for independent study.

Observations in schools preparing for modular-flexible scheduling revealed five areas where the certified personnel functioned in a major way. Major functions according to Trump and Boynham included:

1. The charting of the department
   a. Faculty
      (1) Number of instructors in the department
      (2) Subject area strength of each teacher
      (3) Lecture ability rating for each teacher

b. Facilities
   (1) Room space for large and small groups
   (2) Materials and equipment (on hand and needed)
   (3) Special needs such as laboratory and theater

2. The grouping of students
   a. According to class level
   b. According to ability academically
   c. According to expressed needs
   d. According to team-learning criteria
3. The establishing of "building blocks" such as:
   a. Time blocks
      (1) Pertaining to length of the school day
      (2) Pertaining to the length of the single module
      (3) Pertaining to the length of the weekly module
   b. Group blocks
      (1) Small group size
      (2) Large group size
4. The selection of methods and techniques for teaching using:
   a. Team-teaching
   b. Team-learning
   c. Large group instruction
   d. Small group discussion
   e. Independent study
   f. Laboratory experiences
   g. Others
5. The development of the curriculum especially for modular-flexible scheduling[1]

Homogenous grouping when done according to ability made modular-flexible scheduling more effective, because it enabled teachers to schedule entire groups as they deemed necessary. If an instructor chose, he could meet with some sections a greater number of times per week. Only flexible scheduling allowed this freedom.

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[1]Trump and Boynham, Guide to Better Schools, pp. 118-19.

The Work of the Computer

To assure accurate, efficient, and reliable scheduling, the master schedule, teacher schedules, and individual student schedules were set up by the use of computers. The information given to the computer was as follows:

1. Students grouped according to ability.
2. Teachers assigned to classes according to interests, strength in their subject areas, and abilities.
3. Time patterns for the courses offered (the number of times each class meets per week, including multiple periods, and specific hours to be designated to any course.)
4. The number of classrooms available with the size of sections each room could accommodate and the range of classes that could appropriately be assigned.

Teachers were the real designers of the programs. Computers simply did the manual time consuming paper work. They arranged the curriculum and made considerations which would benefit the student. This control was maintained by the availability of all scheduling data for checking at the time of each decision. Freedom to experiment over a wide range of alternatives has been provided.[2]

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[2] Dwight W. Allen and D. DeLoy, "Stanford's Computer System Gives Scheduling Freedom to Twenty-Six Districts; Stanford School Scheduling System," Nation's Schools, LXXVII (March, 1966), p. 124.

Early spring registration of students was necessary to allow ample time for ability grouping in each course offered and/or requested. Specifications for the computer had to be exact with alternatives clearly set forth. The system processed the input and determined who would teach what, when, where, and to whom. Then, the master schedule was generated and students were assigned to it.[3]

A computer could be expected to:

1. Free teachers from the scheduling burden yet increase their opportunities to make vital educational scheduling decisions.
2. Keep track automatically of a large number of facts about the availability of teachers, students, classrooms, and combinations of these factors that far exceed the capacities of the most astute administrator.
3. Satisfy a higher percentage of student scheduling requirements by accommodating more student and teacher preferences.
4. Allow courses to meet specific objectives by varying the amount of time scheduled or the size and frequency of class meetings.

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[3] Ibid., p. 125.

A computer could not be expected to:

1. Devise a satisfactory schedule if improper information had been programmed into it.
2. Create needed room, additional teachers, or expand time for a program.
3. Cost the same as scheduling by the traditional method if a highly complex program must be developed.[4]

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[4] *Ibid.*, p. 126.

CHAPTER V

DEVELOPMENT OF A MODULAR-FLEXIBLE SCHEDULE

General Stages of Development

It has been observed that modular-flexible scheduling must pass through several developmental stages as it proceeds toward actuation. They are:

1. The "kernel-idea" stage: when an administrator or staff member becomes enthusiastic about the nature of flexible scheduling.
2. The "investigation" stage: when the individual(s) researched in order to become knowledgeable in the subject area.
3. The "involvement" stage: when the person reached out through discussion in an attempt to foster growth of the new plan.
4. The "planning" stage: when enough people became enthusiastic so that the idea moved toward realization.
5. The "actuation" stage: when the school system culminated its plans and began operation within a modular-flexible framework.

Figure 3 has been constructed to depict the growth cone through the five developmental stages.

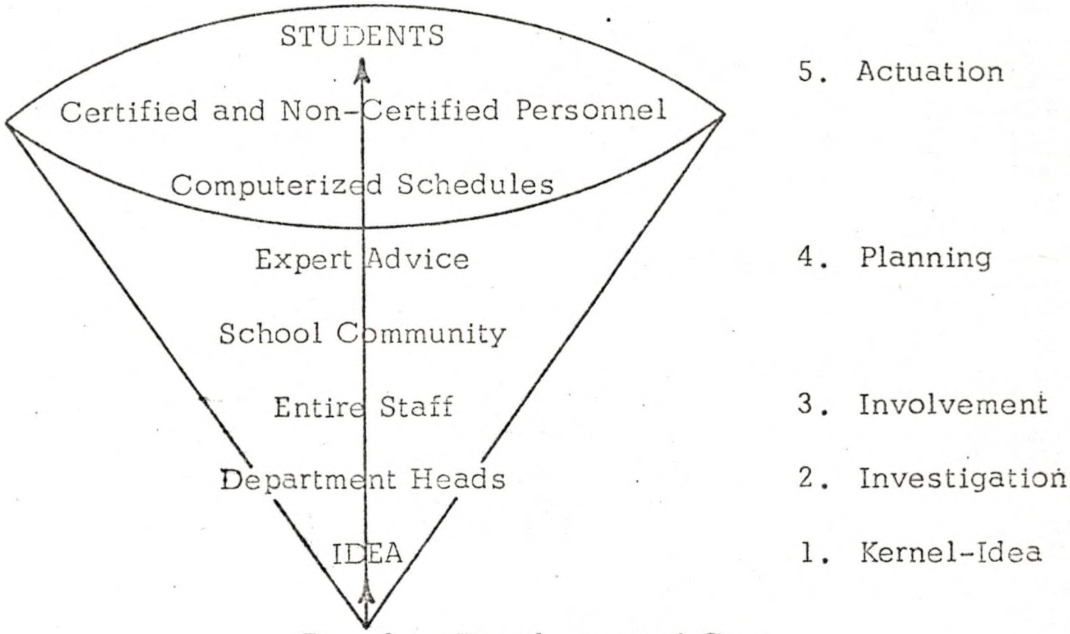

Fig. 3.--Developmental Cone

<u>Specific Stages of Development</u>

Preparation for the change-over to modular-flexible scheduling should follow a well-defined pattern. The following sequence was recommended:

1. Department meeting: members of the department where the kernel-idea was fostered should meet.
   a. If a Director of Education serves the system, his presence should be requested as well as that of the Principal.
   b. Special services people such as the Curriculum Director should also be present.

2. Department heads meeting: this assumes that the sponsoring department was strongly favorable and no administrator was negative.

    a. Administrators should be present at the opening of the meeting to give their support, but it was highly recommended that they leave afterward to allow department heads complete freedom during the discussion.

    b. There should be a full discussion of advantages and disadvantages to students and staff.

   This was the most critical meeting because the support of all department heads was necessary. Non-support of a chairman might split the faculty and cause termination of the proposal.

3. General staff meeting: this meeting should be called by the Principal but the leadership role should be left to the chairman of the department heads committee.

    a. No administrator should be present.

    b. Full faculty discussion of the program.

    c. At the conclusion of the discussion, the faculty should cast a secret ballot indicating continuation or disapproval of further investigation.

4. Development of an outline of the proposal by a faculty-administrator committee.
   a. Outline should be approved by the staff and administration.
   b. Preliminary approval by the Board of Education should be sought at this point.
5. Orientation of the certified personnel should include: in-service training, visitations to schools with modular-flexible programs, alignment of all facilities, equipment, non-certified personnel and students, advice from professionals which may involve training by Stanford Scheduling Specialists.
6. The establishment of well-defined lines of communication so that the entire community has an awareness of action taken and the anticipated outcome.
7. Computer development of a test schedule for thorough study by the staff and administration.
8. Development of a schedule for the system using a corrected model that has been designed specifically for the school.
9. Student orientation to discuss the benefits to them and the disadvantages if any arise.

There should be no rush to install modular-flexible scheduling in a school. The developmental stages may require more than an entire school term, but success of the program depends greatly on the care exercised in planning.

The study included schools with structures having 30, 28, 25, 20, 18, and 15 minute modules. Mod-days were observed to vary in length from 400 to 450 minutes. From the observations made and the discussions held, it was evident that:

1. Long modules (25-30 minutes) generated more wasted time than modules which were somewhat shorter.
2. Long mod-days (420-450 minutes) were less effective than shorter days because of the fatigue element.
3. The shortest mod-periods observed (15-18 minutes) did not allow time to introduce topics satisfactorily.
4. The twenty minute module was selected as the basic time unit because:
    a. In the twenty-minute module concise preparation was necessary, yet the length of the module allowed more meaningful lessons than did longer modules.
    b. The twenty-minute module, or multiples thereof, produced flexibility without confusion of schedule time.
    c. The twenty-minute module when utilized for large group instruction was able to focus student attention without having it wane for that period.

d. The twenty-minute module when doubled gave adequate time for films, filmstrips, tapes, and slides.

e. The twenty-minute module gave adequate time for:

(1) Introductory large group lectures.

(2) Student project presentations.

(3) Motivational activities such as teacher or student demonstrations and experiments.

f. The twenty-minute module (with its multiples) most closely paralleled the needs of physics. When blocks of twenty, forty, sixty, and eighty minutes were set up; large group, small group, laboratory, and independent study were made effectively operational.

(1) One module (twenty minutes) accommodated brief, to the point, large group physics lectures.

(2) Two modules (forty minutes) permitted active student participation without lag during small group discussions.

(3) Two, three and four module periods enabled a wide range of experimentation within one scheduled class period.

5. The twenty module day composed of twenty-minute modules was selected because:

a. Twenty modules per day permitted greater opportunity for students to seek individualized instruction than afforded by the use of fewer modules in the mod-day schedules.

b. Twenty modules per day enabled the students to maintain efficiently the momentum needed for a 400 minute mod-day schedule.

6. The physics mod-week included a minimum of twelve modules. It was recommended that fourteen to sixteen modules be provided on alternate weeks. The 240 minute mod-week should be structured, but the additional two to four modules on alternate weeks should be provided for independent study and project work.

Physics Modular-Flexible Schedule

Building Blocks

Single module class period length		twenty minutes
Mod-day length		twenty modules
Mod-week length		twelve modules minimum (14-16 modules on alternate weeks)
Large group size		40-200 students
Small group size	one instructor would float between the two sub-units	20 students with two sub-units of 10 students each

Laboratory	20 students with extensive utilization of team-learning technique

The facilities necessary for physics instruction within a modular-flexible schedule framework were found to be no more extensive than those for the traditional schedule.

Facilities Found to be Desirable

The following facilities are desirable:

1. A laboratory that has at least twenty stations.
2. A lecture room that has adequate size, acoustics and viewing properties for the total number enrolled in physics.
3. Small group instruction rooms to house the number of groups that meet simultaneously. Individual room size should be sufficient for at least ten students at one seating. Location of the rooms should be in close proximity to the laboratory.

Time Allocation

The study accepted the premise that not all subjects require the same amount of time for adequate understanding. There was no research that supported the "equal time for all subjects" point of view. Time necessary for learning depended upon the content, interest level and student ability. Educators in the schools visited insisted that:

1. Student welfare not be compromised because of scheduling difficulty.
2. Subject content difficulty be related to the ability of the student. Generally, difficult content required more time, but if the students were of high ability, the time they actually required for understanding might be less than for lower ability students to learn less difficult content.

Homogeneous grouping has become a common practice in schools which have installed modular-flexible scheduling, because classes were manipulated more easily when grouping had been accomplished.

It was necessary to "exhort" the staff on the need for grouping as well as the need to allocate variable time periods to different subject areas. Observation and experience have shown that each staff member guards the time allotted for his subject with zeal, while opposing the principle of grouping.

The Student Week as charted in Figure 4 was made with the assumption that the need for variable time periods had been resolved. Allocation of physics modules was made after more than 300 physics students were asked: What subject on your schedule do you feel requires the greatest amount of class time for adequate understanding? Almost nine out of every ten (89 per cent) named physics. Figure 4 has been

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:10- 8:30	P	U	P	B	P
8:30- 8:50	F	U	P	B	P
8:50- 9:10	F	U	P	B	B
9:10- 9:30	B	P	F	B	B
9:30- 9:50	B	P	F	B	C
9:50-10:10	B	P	F	B	F
10:10-10:30	B	P	F	C	F
10:30-10:50	B	D	F	C	F
10:50-11:10	B	D	F	C	F
11:10-11:30	L	L	D	C	F
11:30-11:50	L	L	L	L	F
11:50-12:10	C	E	L	L	L
12:10-12:30	C	E	C	F	L
12:30-12:50	F	E	C	P	F
12:50- 1:10	F	E	C	P	F
1:10- 1:30	F	E	F	P	D
1:30- 1:50	F	F	F	P	D
1:50- 2:10	D	F	F	F	D
2:10- 2:30	D	F	R	F	F
2:30- 2:50	D	F	R	F	F

P = physics 14 modules

F = independent study 33 modules

B = ________________ 14 modules

C = ________________ 10 modules

D = ________________ 9 modules

L = lunch 10 modules

E = ________________ 5 modules

U = ________________ 3 modules

R = ________________ 2 modules

Fig. 4.--Student Schedule

based on a 100 module week consisting of five 20 module days. The symbols used include: ·F (flexible) which equals independent study; B, C, D, E, for other classes; U for unschedule time; and P for physics.

This schedule allowed for thirty-three per cent of the student's time to be expended in independent study. There has been an allocation of three per cent of the student's time for tutorial aid, where the teacher and student work on a one to one basis.

The study affirmed that "it is impossible to picture one schedule for a teacher and have it be valid for all other staff members."[1] There were, however, some generalizations that could be made:

1. The teacher who made group presentations had need for more preparation time than a teacher who worked almost entirely with small groups during discussion.
2. Members of teaching teams must allocate time to meet as a unit during the school week so that they might prepare their instructional participation program.
3. Department heads needed:
    a. Time to meet with department personnel.
    b. Time to meet with the administration.
    c. Time to meet with other department heads to coordinate the school program.

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[1]Manlove and Beggs, <u>Flexible Scheduling</u>, p. 76.

4. Staff members needed time to develop curricular materials.

If teachers were required to meet after school hours, they could not be expected to perform at peak effectiveness, so time should be scheduled within the regular school day for such meetings.

Figure 5 has been developed as the teachers' general pattern for one week. There were no supervisory duties given to the department head in this particular pattern.

"Much of the success of the independent study activities (project work) will depend on both the services students can get and the availability of resources in the instructional materials center."[2] It was recommended that teachers, in addition to the special staff members, be scheduled in the instructional materials center to aid students with their individual learning projects. The teacher schedule should give consideration to the physics instructor for the amount of time that must be devoted to laboratory preparation.

Figure 6 presents a time schedule for representative teachers utilizing a mod-day of twenty modules. The teacher lunch period should include at least two modules. The length of class periods for any individual teacher must fit in the schedule as multiples of twenty. Each teacher has fifteen modules per day as scheduled time and five modules for preparation.

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[2] Ibid., p. 77.

Hours	Modules	Professional Activity	Distribution	For Whom
5	15	Class preparation	Equal each day	All teachers
1	3	Team conferences	At least two per week	Team members
2/3	2	Team leader	Varies	Team leader
1*	3*	Large group lecturer	Varies	Lecturer
5	15	Department heads	Varies	Head only
2**	6**	Work with special students on independent study	Varies	Any staff
As Assigned	As Assigned	Supervision of the large group	Follows a set sequence	Any team member
As Assigned	As Assigned	Instructional materials center assistance	Varies	Any staff
1	3	Department meeting	Varies	All members

*For each lecture made to the large group, the lecturer should be provided with three modules for preparation.

**Students doing particularly advanced work, as well as those doing remedial studies, must meet with their teachers on a regular basis. Time must be provided in the schedule for such instructional activities.

Fig. 5.--Teacher Schedule, Time per Week

Module	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Time Sched.	8:10 :30	:30 :50	8:50 9:10	:10 :30	:30 :50	9:50 10:10	:10 :30	:30 :50	10:50 11:10	:10 :30	:30 :50	11:50 12:10	:10 :30	:30 :50	12:50 1:10	:10 :30	:30 :50	1:50 2:10	:10 :30	:30 :50
Teacher One	X	X	X	X	X	X	X	X	L	L	L	L	X	X	X	X	X	X	X	O
Teacher Two	O	X	X	X	X	X	X	X	X	X	X	L	L	X	X	X	X	X	O	O
Teacher Three	X	X	X	X	X	O	X	X	X	L	L	X	X	O	O	X	X	X	X	X
Teacher Four	X	X	X	O	O	X	X	X	L	L	X	X	X	X	X	X	O	X	X	X
Teacher Five	X	X	O	X	X	O	X	X	X	L	L	X	X	O	X	X	X	X	X	X

Legend: X = scheduled period; O = open period; L = lunch period

Fig. 6.--Teacher Mod-Day Schedule

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was: (1) to examine the basic tenets of modular-flexible scheduling; (2) to develop a particular modular-flexible schedule for secondary school physics; and (3) to incorporate traditional, PSSC, and Harvard Project materials into a single curriculum for use within a flexible framework.

Educators have been concerned with the development of a student-teacher schedule that would enable more individualization of instruction. In this light, the present study has examined closely the radical departure from traditional scheduling referred to as modular-flexible scheduling. It has been found that such scheduling accentuated individualized instruction.

The research has been directed toward the determination of a specific modular-flexible schedule within which a physics curriculum could be best developed. It utilized applicable components of that schedule as the framework for development.

Conclusions

Minneapolis-St. Paul and suburban schools where modular-flexible programs had been installed were visited. These schools' programs varied in duration from the beginning of the fourth year in 1968, to inauguration of the program. Within the limits of the study, findings were summarized as follows:

1. Physics teachers were searching for an instructional mode that would command more student interest, participation and enrollment.
2. A physics curriculum was needed that was more meaningful to the students.
3. Such a curriculum must be adapted to modular-flexible programs.
4. Educators were not fully cognizant that co-development of curriculum and schedule was an essential.
5. The co-development procedure accented the positive aspects of scheduling and curriculum development.
6. The introduction of modular-flexible scheduling should follow a defined procedure, and the decision-making considerations should be sequentially produced. The sequence can be arranged as a ten step continuum. Figure 7 summarizes the sequence for decision-making.

Sequence	Topic	Time Suggestion
First	School Objectives	September-October
Second	Content Selection	November-December
Third	Education Requirement Determination	January
Fourth	Group Size, Frequency, and Duration	January-March
Fifth	Schedule Cycle	March
Sixth	Faculty Utilization	March
Seventh	Student Grouping Specifications	April
Eighth	Team-Teaching Units	April
Ninth	Assignments for the Non-Certified Personnel	April
Tenth	Final Student Program Elections	May

Fig. 7.--Decision-Making Considerations[a]

[a]Donald C. Manlove and David W. Beggs, III, Flexible Scheduling (Bloomington: Indiana University Press, 1965), p. 76.

7. Scheduling elements selected from alternatives in this study have essential qualities which can be summarized as shown in Figure 8.

8. Within the limits of the study, it was concluded that the subject matter of physics did lend itself well to the four phases of modular-flexible scheduling. Modular-flexible scheduling had no magical qualities, but it helped to create a more professional atmosphere for teachers and a more academic atmosphere for students. The schedule provided

Dimension	Preference	Alternatives
Content		1. Unitary subject areas with defined content
	X	2. Unitary subject areas with undefined content
		3. Coordination of more than one subject area with defined content
		4. Coordination of more than one subject area with undefined content
Students		1. Learn in equally balanced groups
	X	2. Learn in varying class-sized groups
Period Length		1. Every period is of equal length
		2. Multiple periods for some courses
	X	3. Period length preset in terms of class sizes and instructional functions
		4. Period length determined by teachers within an assigned block for one or more subjects
		5. No assigned period length made
Time		1. Standard distribution of time for all subjects
		2. Standard distribution of time but varies with grade level
	X	3. Various distributions of time for each subject
		4. Distribution of time varies; established on ad hoc basis
Cycle		1. One day
		2. Two days
	X	3. One week
		4. Not set; determined on an ad hoc basis

Figure 8--Continued

Dimension	Preference	Alternatives
Instructional Media	X	1. Media used on an ad hoc basis 2. Planned media; established order 3. Media used as part of individual study
Facilities		1. Multi-purpose facilities 2. Highly specialized facilities
	X	3. Semi-specialized facilities
Teachers		1. One teacher working with a given number of students in varying class-sized groups 2. One teacher working with a given number of students in equally balanced groups 3. A team of teachers (three or more) working with a given number of students in equally balanced groups
	X	4. A team of teachers working with a given number of students in varying class-sized groups
Non-Certified Instructional Aides		1. Members of teaching teams
	X	2. Service personnel who assist on an ad hoc basis

Fig. 8.--Scheduling Elements[a]

[a]Donald C. Manlove and David W. Beggs, III, Flexible Scheduling (Bloomington: Indiana University Press, 1965), p. 76.

many advantages for students and allowed them to meet their individual needs and interests.[1] ". . . if educational leadership engages in a never-ending search experimentally to seek soundly based answers to the question of how to return the enlightened use of time, space, numbers, and curriculum to the teachers and students, then flexible scheduling is absolutely fundamental in the search for better education."[2]

9. The study demonstrated markedly that small group activities, large group instruction, laboratory experiences, and independent study had strong affinities for the newly developed physics curriculum completed in conjunction with the flexible program. Figures 9, 10, 11, and 12 summarize the four phases of instruction which were basic to modular-flexible scheduling.

An objective, statistical evaluation of modular-flexible scheduling has not been made. However, a practical-experience evaluation was related by staff members who have taught within such a framework. They maintained that teachers were working harder; but that their work was

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[1]T. G. Leigh, "Big Opportunities in Small Schools Through Flexible Modular Scheduling," Journal of Secondary Education, LI (March, 1967), p. 178.

[2]Trump, "Flexible Scheduling," p. 143.

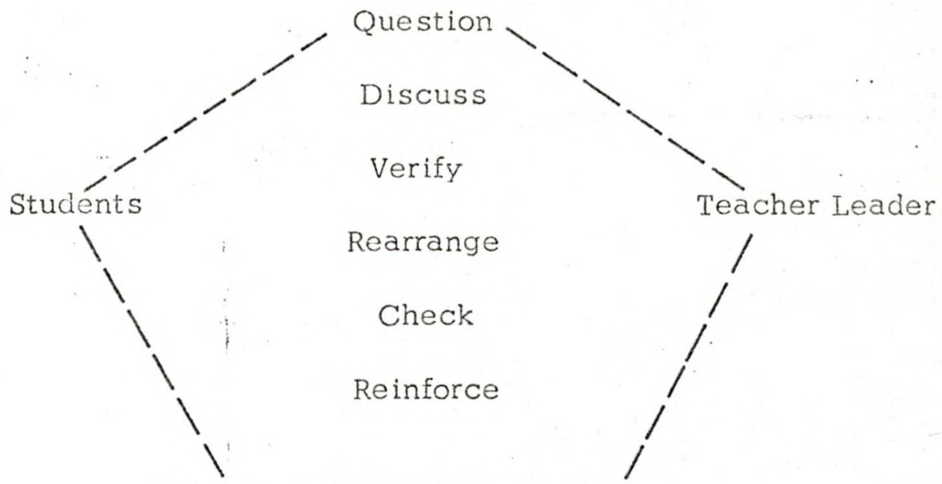

Fig. 9.--Small Group Activities

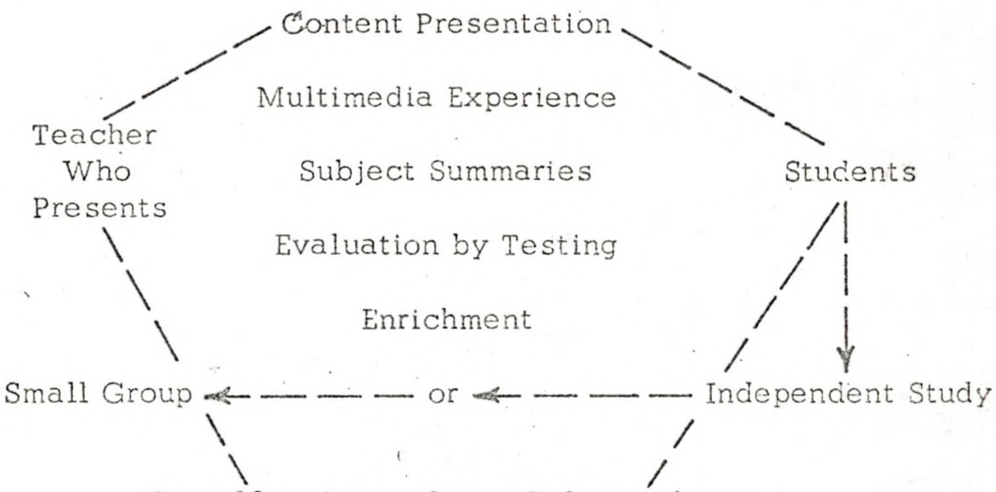

Fig. 10.--Large Group Relationships

The teacher is a:

1. Vehicle of Group Motivation
2. Director of Learning
3. Source of Ideas, Facts, and Explanations

The student will:

1. Take notes
2. View films, transparencies, flannel board displays, and other idea presentations
3. Do test work
4. Listen to the teacher
5. Get background material for small group discussion and independent study work

Fig. 11.--Large Group Teaching

	Practice	
	Investigate	
Students	Application on Job	Teacher Leader
	Problem Solving	
	Simulation	

Fig. 12.--Laboratory Activities

conducted on a more professional level, and hence, they were receiving more satisfaction.

Librarians stated that student response had produced extensive use of library facilities and had decreased disciplinary problems. Non-fiction book usage had increased markedly. During independent study in schools with established programs, students elected to go to resource centers, libraries and study areas for most of their unscheduled time.[3]

Extended evaluation of modular-flexible scheduling will be forthcoming. So far, the program has proved to be effective and efficient.

Recommendations

This study represented a beginning. The curriculum guide, found in Appendix C, has limitations. The guide was recommended as a core around which each school may build a physics curriculum that was adapted to its facilities and staff.

The curriculum guide has allocated modules for all major sections. The modules were selected to permit a combined (deduction-induction) approach. Time should be allotted to study the real meaning of "induction." As a method of instruction, it requires an attitudinal change in the teacher. It is not as easily attained as commonly believed.

The curriculum presented contains information gathered from many sources. It may be considered as a substantial secondary physics guide. The teacher who may choose to use the materials should remember that it has been designed for twenty-minute modules. If a different-sized module is used, re-assignment of time units would be required.

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[3] Allen and DeLoy, Nation's Schools, p. 124.

Consideration has been given in the guide to the three domains of learning. The cognitive, psychomotor and affective domains were incorporated in the scheme used. It was recommended that the reader carefully study the processes, contents and outcomes for each of the domains. It was especially recommended that the user become fully aware of the affective learning domain. The enrollment problem faced by educators on all levels where physics is being taught can be solved only if prime consideration is given to this domain. Physics instructors, in fact all teachers, should inculcate the domains in their teaching if they wish to become effective. If the peak level of student learning is to be attained, all domains must be incorporated. The entire staff should devote considerable study to the materials presented in Appendix A.

The study revealed that only three of the seventeen schools had planned for an evaluation of their instructional program. There were two basic reasons for this apparent lack of evaluation:

1. Modular-flexible scheduling was a very recent venture.
2. Measuring instruments, techniques, and methods have not been established.

The most complete evaluation conducted throughout the area was done by South High School in Minneapolis, Minnesota. Appendix B should be studied carefully by those schools contemplating evaluation.

The scope of this study has been at least equalled by the problem of ever-decreasing enrollments in high school physics. Within a flexible schedule the curriculum guide and its presentation methods and techniques and professional consideration of the learning domains will meet successfully the declining enrollment problem.

APPENDICES

APPENDIX A

The Cognitive Domain: Knowledge, Intellectual Abilities and Skills

Processes	Contents	Outcomes
Perceiving Remembering	Figural-Concrete Stimuli or Signals Perceived Through Senses, Actual Things Seen, Heard, Felt, etc.	Knowledge of: 1. Specifics Terminology Facts
Comprehending Translating Interpreting Extrapolating	Symbolic-Letters, Digits, and Other Signs or Signals Usually Organized in General Systems Such as the Alphabet	2. Ways and Means of Dealing with Specifics Conventions Trends and Sequences Classification and Categories Criteria Methodology
Discriminating Integrating	Semantic-Verbal Meanings or Ideas	
Applications Abstracting Generalizing Imagining Thinking Inventing Problem Solving Creating		3. Universals and Abstractions in a Field; Principles and Generalizations, Theories and Structures
Analyzing Synthesizing Evaluation		Abilities and Skills in Utilizing All Processes in Column One When Dealing With Natural Phenomena

The Psychomotor Domain: Manipulative, Muscular, or Motor Abilities and Skills

Processes	Contents	Outcomes
Strength and Endurance	Bodily Manipulation in Such Activities as:	Psychomotor Outcomes are Often Closely Related to Cognitive Outcomes; e.g., Writing, Drawing
Speed	Walking	Using Special Instruments with Precision and Rhythm
Impulsion	Running	
Precision	Skipping	
Coordination	Jumping, etc.	
Flexibility	Object-Manipulation:	
	Tools	
	Pencils	
	Typewriter Keys	
	Scientific Apparatus, etc.	
	Vocal Activities	

The Affective Domain: Attitudes, Interests, Values, and Appreciations

Processes

Receiving
- Awareness
- Willingness to Receive
- Controlled or Selected Attention

Responding
- Acquiescence in Response
- Willingness to Respond
- Satisfaction in Response

Valuing
- Acceptance of a Value
- Preference for a Value
- Commitment

Organization
- Conceptualization of a Value
- Organization of a Value System
- Characterization by a Value or Value Complex

Generalized Set Characterization

Contents

Specific Tastes or Aesthetic Choice
Style of Life
Group Codes
Morals
Conscience
Intermalization of a Set of Specified Ideals or Values
Identification
Pursuance of a Value or Ideal
Motivation to Act Out a Behavior

Outcomes

Sensitivity, Empathy, Tolerance, Devotion, Compliance of Obedience, Carefulness, Neatness, Responsibility, Alertness, Openmindedness, Ethical Behavior, a Consistent Philosophy, etc.

APPENDIX B

Progress Report on the Modular-Flexible Scheduling Program at Minneapolis: South High School

Introduction: Preparation for the modular-flexible schedule at South High School began during the school year 1966-67. In-service meetings were held during the spring of 1967 for the purpose of introducing the general concept of modular-flexible scheduling. Teachers and other staff visited schools where the schedule was established. During the summer of 1967, staff at South High School participated in development experiences centering around curriculum, and several staff members visited Stanford University at Palo Alto, California for more complete information.

Evaluation of the program was conducted by a South High School staff committee. This committee was elected during early September 1967 and consisted of the school principal and five elected staff members. Members of the research team for federal projects and the Minneapolis schools' Consultant in Educational Research, also, participated in the committee meetings. The primary responsibility of the committee was to work out ways and means of evaluating the modular-flexible program. It was anticipated that the evaluation would be more valid and better received by the staff if conducted by elected representatives rather than by external agencies.

Procedures: Questionnaires were used as the major means for obtaining information regarding the program. Alternative means such as standardized test were either not available or were impractical at the time when they were needed. However, the Minnesota Scholastic Aptitude Tests and the English Coop Tests, given over a number of years could have provided a useful record of trends. Other data which could have been used, if available, would have been dropout rates, attendance, and failure rate comparisons over the past few years.

Two similar, nearly identical, questionnaires were developed by the committee during a series of meetings in the fall of 1967. One questionnaire was for teachers' responses and the second questionnaire was for students' responses. Items and questions were worded so as to compare student and teacher responses to a number of significant items. In general, the areas covered in the questionnaire were as follows:

1. Respondent description
2. Teaching (learning) conditions
3. Supplementary study areas
4. Grouping methods
5. Use of unstructured student time
6. Comparison of flexible and regular programs

These questionnaires were administered during the week of February 5, 1968 during an extended home room period. Every effort was made to pick up absentees, to insure respondent anonymity, and to obtain full cooperation and return of the questionnaires. The return for the staff approached 99 per cent and also was high for the students with a total of 942 student respondents.

Questionnaire

A. What statement or position best reflects your present attitude towards modular-flexible scheduling? This should be answered by use of a brief non-signed paragraph from each staff member and student.

B. What are the present program needs? According to the:

1. Staff members

a.	Student accountability	more	less
b.	Administrative direction	more	less
c.	Progressive structuring of student unscheduled time--least to most from sophomores to seniors	yes	no
d.	Flexibility in scheduling for the various departments	more	less
e.	Student pre-preparation for the program	more	less
f.	Schedule continuity in large group, small group, laboratory, etc.	more	less

2. Students

a.	Schedule continuity for large group, small group, laboratory, etc.	more	less
b.	Experiences in the use of unstructured time	more	less

C. How would you rate your personal success with the program?

1. Good
2. Average
3. Poor

D. Respond to the following:

1. Do you have enough supplies in your course?	yes	no
2. Do you have enough equipment?	yes	no
3. Are learning facilities adequate?	yes	no
4. Is your schedule satisfactory?	yes	no
5. Were you given adequate preparation?	yes	no
6. Was your pre-planning adequate?	yes	no
7. Are you able to use unstructured time as you like?	yes	no
8. Would you recommend more unstructured time?	yes	no
9. Does your unstructured time coincide with that of your instructor? or student?	yes	no
10. Should a student be required to spend a set amount of his unstructured time in each of his subjects?	yes	no
11. Should student be held responsible for usage of unstructured time?	yes	no
12. Should teachers use a contractual system for students?	yes	no
13. Do you prefer the assignment system on a class basis?	yes	no
14. Does structured time permit adequate discussion of subject materials?	yes	no
15. Do too many students use their unstructured time badly?	yes	no

E. Rate the following areas:

	excellent	good	adequate	poor
1. Resource centers	_____	_____	_____	_____
2. Library	_____	_____	_____	_____
3. Study areas	_____	_____	_____	_____
4. Large group	_____	_____	_____	_____
5. Small group	_____	_____	_____	_____
6. Laboratory (open)	_____	_____	_____	_____
7. Laboratory (assign)	_____	_____	_____	_____
8. Independent study	_____	_____	_____	_____

F. How would you compare regular scheduling with the modular program in regards to: (teachers only respond to this)

Under modular scheduling	increased	same	decreased
1. Teacher-teacher cooperation has	____	____	____
2. Teacher clerical duties have	____	____	____
3. Paraprofessional help needs have	____	____	____
4. Adequate coverage of subject materials has	____	____	____
5. Student learning has	____	____	____
6. Adequacy in meeting student needs has	____	____	____
7. Class interruptions have	____	____	____
8. Value of departmental meetings has	____	____	____
9. Student disciplinary problems have	____	____	____
10. Teacher-administrator cooperation has	____	____	____

G. How would you compare regular scheduling with the modular program in regards to: (students only respond to this)

Under modular scheduling	increased	same	decreased
1. Adequacy of instruction has	____	____	____
2. Learning opportunities presented have	____	____	____
3. Student self-motivation has	____	____	____
4. Teacher motivation of the student has	____	____	____
5. Student disciplinary problems have	____	____	____
6. Student awareness of democratic procedures has	____	____	____
7. Variable class period length value has	____	____	____
8. Good student-teacher relations have	____	____	____
9. Responsible citizenry for students has	____	____	____
10. Rapidity of student progress has	____	____	____

Questionnaire Results

The forms were key punched, processed and summarized by members of the Federal Projects research team. The data were arranged in tabular form with numbers of responses converted to percentages of response in order to compare responses of different groups to the same questions.

The discussion centered around areas included in the questionnaire and a comparison of percentages of response according to the following categories:

1. Teacher-student responses
2. Student's grade level
3. Student's grade point average (GPA)
4. Student's vocational plans

In general, the opinions of teachers were about evenly divided with regard to the teaching conditions. These conditions included availability of supplies, equipment, facilities, program scheduling and student preparation. Although these items were not unique to modular-flexible scheduling, heavy dissatisfaction with any single item could have easily influenced the entire program's effectiveness. They felt, however, that the students were not well prepared for the new program. In comparison to the teachers, the students were more favorably disposed toward their learning conditions. When categorized according to claimed grade point average, students who were failing favored supply, equipment and facilities and were less enthusiastic about their individual schedules than students who were passing. When categorized according to student grade levels, seniors were more critical of facilities than sophomores and juniors. There were no differences according to vocational and educational plans.

Supplementary study areas: Supplementary study areas included the resource centers, library and study areas where students were more or less free to enter and to direct their own activities. The perceived effectiveness of these areas was rated on a five point scale ranging from inadequate (1) through excellent (5).

In general, both the teachers and students rated the study areas as adequate, and teachers were somewhat more critical than the students. There were no meaningful differences in responses with regard to supplementary study areas, according to student's grade level, student's claimed GPA, or student's vocational plans.

Grouping methods: Grouping methods included grouping students for instruction and learning as follows:

1. Large group instruction
2. Assigned laboratories
3. Open laboratories
4. Small group discussion

In general, both teachers and students tended to rate these various groupings as adequate in value with the teachers being somewhat more critical than the students. The grouping method rated highest by both teachers and students was small group instruction. There were no meaningful differences in response with regard to students' groupings, according to student's grade level, student's claimed GPA or student's vocational plans.

Use of unstructured time: There were some areas of agreement and some differences of opinion between students and teachers with regard to unstructured time.

Responses of students and teachers were almost evenly divided as to whether or not they could contact each other during unstructured time. A larger percentage of students (69 per cent) than teachers (49 per cent) felt that they were able to use their unstructured time satisfactorily. Students who were failing were less satisfied with the use of unstructured time than were students who were passing. Neither teachers nor students wanted more unstructured time; but 63 per cent of the staff as compared with 13 per cent of the students felt that the students should have less unstructured time.

Most teachers (61 per cent) required students to report to them for some portion of the student's unstructured time. Most of the students (71 per cent) felt that this was not necessary and not in keeping with the spirit of the program. Students who were failing were most receptive while "A" students were least receptive to the idea that portions of their unstructured time be spent with a teacher.

Most teachers felt that the students were not assuming any responsibility for the use of their unstructured time other than what their grades reflected. The students were about evenly divided as to whether or not they should accept any responsibility other than grades. However, there were differences among the students according to the levels of achievement. According to their GPA 71 per cent of the "A" students, as compared with 37 per cent of the "F" students, felt that grades should be the only criteria of responsibility.

Most teachers (74 per cent) felt that the students spent too much time in the commons while students were about evenly divided on the matter. However, the "A" students were much less concerned with this question than were the remaining students.

Comparison of modular-flexible and regular programs: The teachers were asked to rate a number of items on a five point scale ranging from considerably decreased (1), the same (3), through considerably increased (5). For purposes of this discussion the categories have been reduced to three; decreased, the same and increased. According to the teachers the following items or areas had been increased:

1. Teacher to teacher cooperation
2. Teacher's clerical duties
3. Need for paraprofessional help
4. Flexibility in meeting individual needs

The following items or areas had remained about the same or had increased slightly:

1. The amount of subject matter covered
2. The amount of subject matter learned

Teacher and student opinion: At the end of both the student's and teacher's questionnaire was an open ended question asking for that "statement or position which best reflects your present attitude towards modular-flexible scheduling." Both students and teachers responded positively but with qualifications. The interpretation meant, so far so good, but improvements were needed and in order.

Summary

The general reaction towards modular-flexible scheduling by both the teachers and students was positive. Most students and teachers, however, qualified their acceptance with constructive criticism. Their attitudes seemed to be that the program was working about as well as could be expected considering the unprecedented approach. Areas needing more attention and possible change as suggested by staff and students were as follows:

1. Student accountability
2. Administrative direction
3. Structuring of unscheduled time
4. Flexibility in scheduling

5. More effective student preparation for the program
6. Continuous in-service and curriculum development
7. More continuity between large group instruction and small group instruction.
8. Realistic demands upon student's unscheduled time
9. Improvement in general teaching and learning conditions, including the resource and study areas

The teachers and students had similar perceptions with regard to most aspects of the program, although the teachers were somewhat more critical. One area of difference, was in the use of unscheduled time. In general, teachers wanted a reduction in student's unscheduled time, while the students did not want any reduction.

There were few differences among the students when categorized according to grade level, claimed grade point average, and vocational plans. The major difference was that the "A" students preferred much less structured conditions than "F" students.

APPENDIX C

PHYSICS CURRICULUM GUIDE

Introductory Note

Physics, perhaps, more than any other science has set forth a challenge to mankind that all the world's people life together and benefit through its discoveries.

The physicist has produced the mechanisms that have caused distances to become relatively small and have brought the people of the world closer together. This relative shrinking of the earth travel time-table demands that people live together in harmony. The virtual erasing of geography as a separating factor has cast man in a new role. This role challenges man's ingenuity to organize his mental, physical and spiritual resources so that international peace and prosperity might prevail.

The study of physics increases perspective and helps the student visualize "tomorrow." This tomorrow will be made richer by the discoveries that physics will bring to light.

Perhaps, this guide will open doorways and broaden horizons for the generation of physicists now in the making, whose discoveries might produce a more abundant life for us all.

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UNIT I

MATHEMATICAL REVIEW

Introductory Note

One of the principal assets of physics is that it introduces the learner to the functional value of mathematics. A quantitative science such as physics demonstrates the importance of mathematics to understanding. Mathematics clarifies and simplifies an otherwise complex body of subject matter.

A larger measure of success will be experienced by those physics students who have become well grounded in basic mathematics. Ideally, such students would have had algebra, geometry, and elementary trigonometry as prerequisites and would be taking advanced mathematics concurrently with physics. Realistically, the physics student should be required to have had algebra. Additional courses must not be considered mandatory to student success unless homogeneous grouping has established a select section.

Some of the basic mathematics necessary for an introductory physics course has been reviewed in this guide. The precepts presented should be studied by the individual student. Concepts should be dealt with by the instructor and students in a more sophisticated manner when the opportunity presents itself. If basic mathematics has been recognized as a basic tool in the study of physics, measurement is an observable factor and cannot be separated from mathematics.

Elementary physics is congruent with observation in several aspects where it deals with reality and fact. Sometimes, the limits of observation blend imperceptibly with interpretation. The imaginative and creative faculties of the mind have given great breadth and depth to the study of physics and have made its study requisite for understanding our physical world.

This course has been geared specifically to reach most secondary high school students. It has been carefully selective in the materials presented and the method of presentation so that understanding would not be limited only to the select few.

The writer has attempted to design the structure so that the guide will fit into a modular-flexible schedule.

The time units chosen to be the "mods" for this curriculum guide were twenty minutes in length. During the school week, the total student time exposure to physics has been set at 240 minutes.

The class unit size that permits most adequate functioning has been set at twenty pupils.

A basic pattern from which fluidity can come has been portrayed on the following pages.

GROUP A (20 Students)

Period	Monday	Tuesday	Wednesday	Thursday	Friday
1st	Large Group	Lab.	Lab.	Independent Study	Open
2nd	Open	Lab.	Lab.	Independent Study	Open
3rd	Open	Small Group	Lab.	Independent Study	Large Group
4th	Open	Open	Lab.	Open	Large Group

GROUP B (20 Students)

Period	Monday	Tuesday	Wednesday	Thursday	Friday
1st	Large Group	Open	Independent Study	Lab.	Open
2nd	Open	Small Group	Independent Study	Lab.	Open
3rd	Open	Lab.	Independent Study	Lab.	Large Group
4th	Open	Lab.	Open	Lab.	Large Group

Unit Objectives

1. To present the functional mathematics necessary for the understanding of a high school physics course.

2. To develop an appreciation for the interrelatedness of mathematics and physics.

3. To direct attention toward conceptualization of ideas garnered from mathematical computations using empirical data collected from experimental observation.

4. To foster the awareness that mathematics and physics instructors should exchange ideas, methodology, and techniques that are found to be fruitful.

5. To inspire students to develop dexterity in certain operational procedures such as the structuring of vector forces and the use of the slide rule.

Suggested Outline for Presentation

I. Mathematics Review
   A. Algebraic Needs
      1. Pertaining to number systems
         a) Algebraic addition
         b) Algebraic multiplication
      2. Pertaining to operations that are special properties of different number systems
         a) Algebraic subtraction
         b) Algebraic division
      3. Related to exponents and their:
         a) Functions
         b) Fractional values
      4. Related to problem solving that requires:
         a) An understanding of square root
         b) Using quadratic equation
   B. Geometric Needs
      1. Involving proportions
         a) Direct proportionality
         b) Inverse proportionality
      2. Pythagorean Theorem
      3. Slope concept
   C. Trigonometric Needs
      1. Trigonometric functions
         a) Sines
         b) Cosines
         c) Tangents
      2. Related to non-right triangles
         a) Law of Sines
         b) Law of Cosines
   D. Vector Analysis Needs
      1. Pertaining to vectors acting along the same axis
         a) Parallel (same direction)
         b) Parallel (opposite direction)
         c) Resolution of such vectors
      2. Related to vectors acting in a coordinate system that is:
         (a) Rectangular
            (1) Graphic solution by
               (a) Addition of vectors
               (b) Subtraction of vectors

(2) Analytic solution for
(a) Vectors acting at right angles
(b) Resolution of vectors into their components
(b) Non-rectangular
(1) Graphic solution
(2) Analytical solution

E. Understanding and Proper Use of
1. Significant figures
2. Scientific notation

F. Slide Rule

II. Mathematics Pre-test

Procedural Activities

Algebraic Needs

Basic Operations: Large Group Presentation (One Module)

The method of using symbols for performing operations on number systems is called algebra. It frequently permits us to solve problems that would be unsolvable by any other means. The two most basic operations in algebra are addition and multiplication. Subtraction and division are special properties which characterize some other number systems. The theory of sets will not be studied. This presentation has been limited to the manipulations basic to solving those problems in an introductory physics course.

I. Basic operations
   A. Addition
      1. Commutative addition: $a + b = b + a$
      2. Associative addition: $a + (b + c) = (a + b) + c$
   B. Multiplication
      1. Commutative multiplication: $a \cdot b = b \cdot a$
      2. Associative multiplication: $a (b \cdot c) = (a \cdot b) c$
      3. Distributive multiplication: $a (b + c) = (a \cdot b) + (a \cdot c)$

II. Special operations
   A. Subtraction: $a - b = c$
   B. Division: If $a = b \cdot c$, then $a/b = c$

III. Brackets and parentheses are used to show order
   A. Example: $(a + b) c - e = f$
   B. Order of operations for the example:

$$a + b = x$$
$$x \cdot c = y$$
$$y/d = z$$
$$z - e = f$$

IV. Superscript numbers which indicate that a quantity is multiplied by itself a number of times are called exponents

A. Any quantity raised to the zero exponent equals <u>one</u>
   1. $a^0 = 1$
   2. $3^0 = 1$
   3. $x^0 = 1$

B. The process used to raise a number to a power (also a quantity) that is greater than one or equal to one
   1. $a^1 = a$
   2. $a^2 = a \cdot a$
   3. $a^3 = a \cdot a \cdot a$
   4. $a^n = a \cdot a \cdot a \cdot a \ldots$

C. If a quantity raised to some power is multiplied by the same quantity raised to a different power, the quantity raised to the <u>sum</u> of the two powers is the <u>result</u>
   1. $a^m \cdot a^n = a^{m+n}$
   2. $a^3 \cdot a^2 = a^{3+2} = (a \cdot a \cdot a)(a \cdot a) = a^5$

D. If a quantity raised to a power is in turn raised to another power, the result is the product of the powers for the quantity
   1. $(a^m)^n = a^{mn}$
   2. $(a^2)^4 = a^{2 \cdot 4} = (a \cdot a)(a \cdot a)(a \cdot a)(a \cdot a) = a^8$

E. Negative exponents are used to express reciprocal quantities
   1. $\frac{1}{a} = a^{-1}$
   2. $\frac{1}{a^3} = a^{-3}$
   3. $\frac{1}{a^n} = a^{-n}$

F. When exponents are fractions, the extraction of a root is the operation to be performed
   1. $a^{1/2} = \sqrt[2]{a}$
   2. $a^{1/4} = \sqrt[4]{a}$
   3. $a^{1/n} = \sqrt[n]{a}$

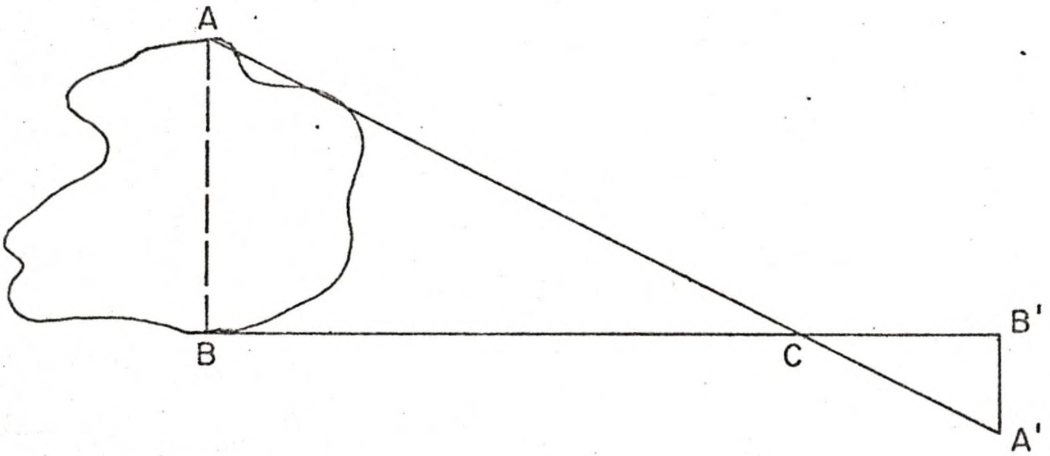
Geometric Needs

<u>Large Group Presentation (One Module for Each Division)</u>

Geometry is the branch of mathematics that deals with lines, angles, surfaces, and solids. There are several important concepts in geometry that are very useful in the study of physics. The most basic are:

Triangulation (One Module)

A direct measurement is not practical in many physical situations. One method used to solve problems where actual measurement is prohibitively difficult is by triangulation. An example follows: refer to the diagram for the necessary visual aids.



If we needed to determine the width of the lake at AB, it can readily be seen that direct measurement would be difficult. A close approximation can be calculated by use of similar triangles. The solution is:

ABC A'B'C'

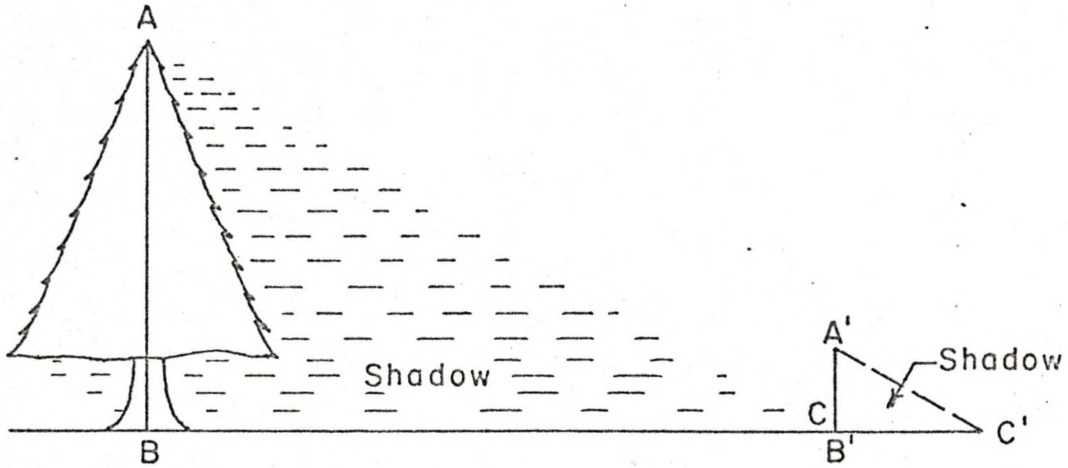
$BC/B'C = AB/A'B'$

$$AB = \frac{BC \cdot A'B'}{B'C}$$

Let BC = 2000 feet
B'C = 40 feet
A'B' = 30 feet

Then, AB = __________

The shadow method for determining the height of a tree is another example of the use of triangulation. The following diagram will picture the method and make it readily understood.



AB = height of tree

A'B' = meter stick

BC = length of tree shadow

B'C' = stick shadow

The same method of calculation is employed as for the lake problem. It is suggested that the class (small group units) carry out field experiences to reinforce their learning. A teacher aide should work with ten students in a laboratory situation while another ten work outside.

Proportionality (One Module)

A symmetrical arrangement indicating the equality of ratios is referred to as proportionality. The concept of proportionality is encountered frequently in physics, because it is largely an empirical science and results of scientific experiments are often proportional relationships. The two basic kinds of proportions are direct and inverse.

Direct proportions.--A direct proportion is a constant ratio between two quantities. Increasing one quantity must bring an increase in the other quantity, so that the ratio between the two remains the same. If quantity X is related to quantity Y so that:

$$X \propto Y$$

$$2X \propto 2Y$$

$$3X \propto 3Y$$

then, they are said to be directly proportional. The ratio between X and Y remains the same and is referred to as the proportionality constant k.

$$\frac{X}{Y} = k = \text{constant}$$

The relationship which exists between the circumference c of any circle and its diameter d is another example of a direct proportion.

$$c \propto d$$

$$c = k\,d$$

$$k = \frac{c}{d}$$

The relationship between the mass and volume of a homogeneous substance also expresses proportionality. This relationship is such that:

$$\text{mass} \propto \text{volume}$$

$$m \propto v$$

$$m = k\,v$$

$$k = \frac{m}{v}$$

The proportionality constant k is commonly called the mass density. A direct proportion may exist between a quantity and a power of another quantity:

$a = k\,b^n$ where b is a quantity to the nth power.

$k = \dfrac{a}{b^n}$ k is the proportionality constant.

It should be understood that a can be proportional to b^2 or b^3. It is also possible that doubling a could cause b to quadruple or change by a multiple of b^n.

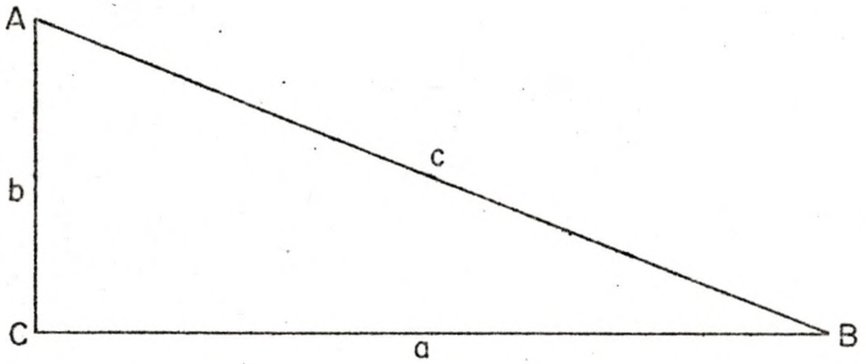
Inverse proportions.--An inverse proportion exists when an increase in one quantity produces a decrease in another quantity. This relationship is such that:

$$a \propto \frac{1}{b} \quad \text{or} \quad a = \frac{k}{b^n} = kb^{-n}$$

A quantity which varies inversely with the power of another quantity is manipulated in this manner.

Pythagorean Theorem (One Module)

The square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides.

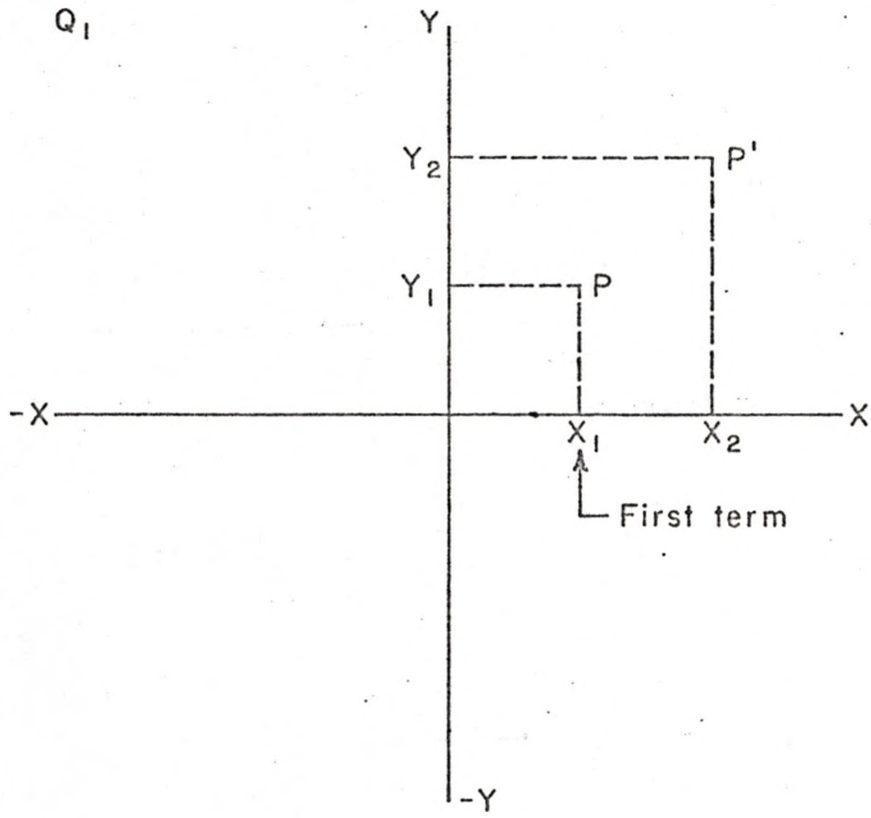


$$c^2 = a^2 + b^2$$

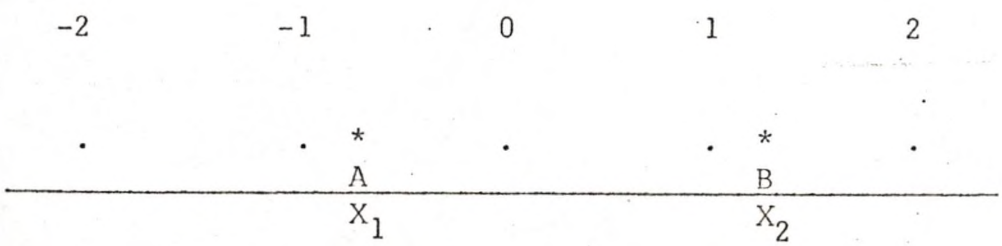
Slope Concept: Large Group (Two Modules)

Two number scales are used when locating a point on a plane. The rectangular coordinate system is most commonly used, although scales can be in different positions. The scales or axes are at right angles to each other in this system. In the rectangular coordinate system, the horizontal scale is referred to as the X axis and the vertical scale becomes the Y axis. These intersecting axes divide the plane into four quadrants, known as Q_1, Q_2, Q_3, and Q_4. The rectangular coordinate system introduces the concept of ordered pairs. The elements selected must be arranged in an ordinal manner. In the diagram that follows, points P and P' are located by the use of two ordered pairs (X_1, Y_1) and

(X_2, Y_2). It is customary that the first term designated be placed on the X-axis. An ordered pair locates only one point in the plane.

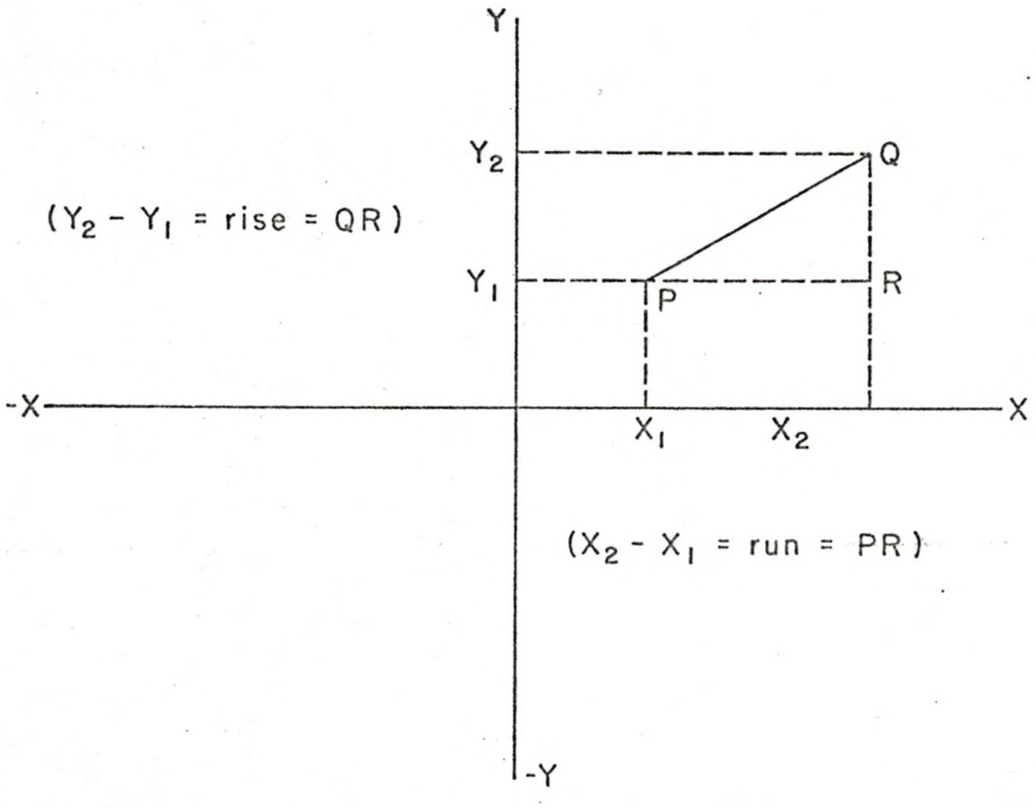


If several points are located within a line, the distance between any two points is a line segment. Consider the diagram:



The distance AB, which is equal to $(X_2 - X_1)$, is a line segment. The distance given by the $(X_2 - X_1)$ relationship may be either positive or negative. It is called the directed distance. Directed distance is determined by subtracting the coordinate of the initial point X_1 from the final coordinate X_2. Due to direction, the line segment AB which equals $(X_2 - X_1)$ is said to be positive, while BA $(X_1 - X_2)$ is designated as negative. The study of mechanics employs directed distances.

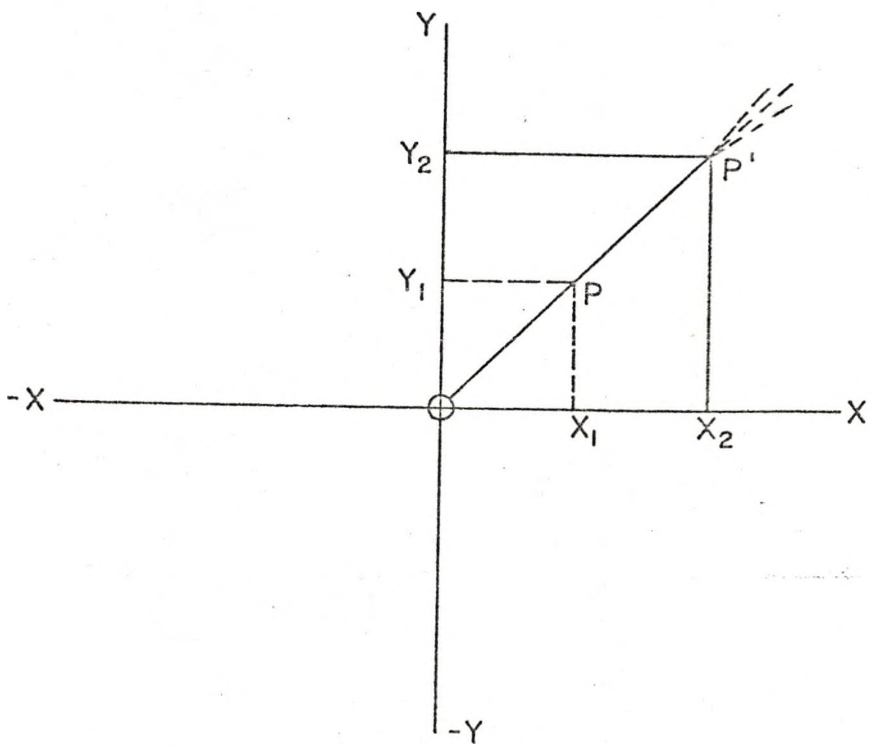
In the diagram below, a line has been drawn that is oblique to both coordinate axes X and Y. Through points P and Q and parallel to the X and Y axes respectively, the lines PR and QR have been constructed. The directed distance PR which parallels the X-axis is called the <u>run</u>,



while line QR which parallels the Y-axis is called the <u>rise</u>. Slope is defined as the ratio of rise/run (QR/PR) and is a constant for a straight line. If the coordinates of P are (X_1, Y_1) and the coordinates of Q are (X_2, Y_2), the slope m, equals $(Y_2 - Y_1)$ $(X_2 - X_1)$.

$$\text{Slope} = m = \frac{Y2 - Y1}{X_2 - X_1} = \frac{\text{rise}}{\text{run}}$$

The slope of a curve at any point is illustrated by the slope of the tangential line through P. Graphic analysis of empirical data is often significant in the field of physics. Working between fixed points, interpolating, is permissible, however, working beyond point P' without additional data, extrapolating, may lead to inaccuracy. Sometimes, extrapolation is important.



Trigonometric Needs

<u>Trigonometry: Large Group (Two Modules)</u>

Trigonometric functions can be related to a right triangle by the following:

Sine function: pertaining to right triangles.

$$\text{Sin} \quad \text{BAC} = \sin\theta = a/c = \frac{\text{side opposite } \theta}{\text{hypotenuse}}$$

Cosine function: pertaining to right triangles.

$$\cos\theta = b/c = \frac{\text{side adjacent } \theta}{\text{hypotenuse}}$$

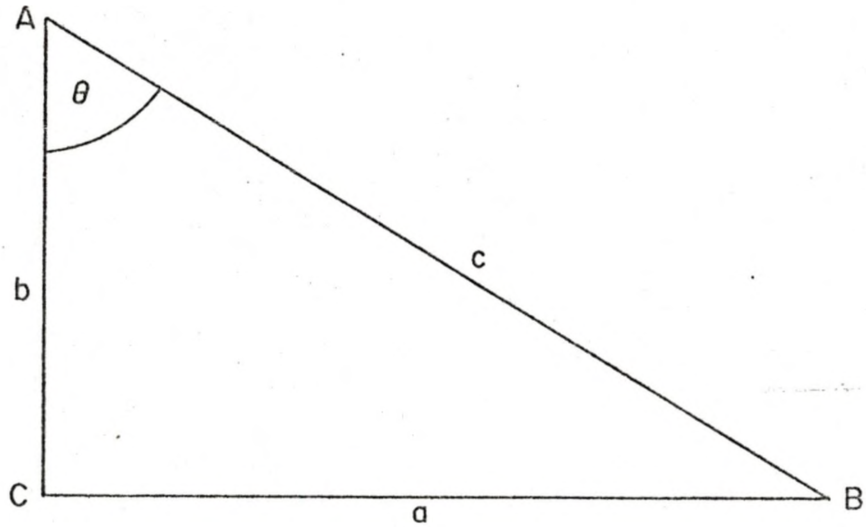
Another very useful relationship for right triangles:

$$\tan\theta = a/b = \frac{\text{side opposite } \theta}{\text{side adjacent}}$$

$$\cot\theta = b/a$$

$$\sec\theta = c/b$$

$$\csc\theta = c/a$$



The Law of Sines and the Law of Cosines can be used with oblique triangles:

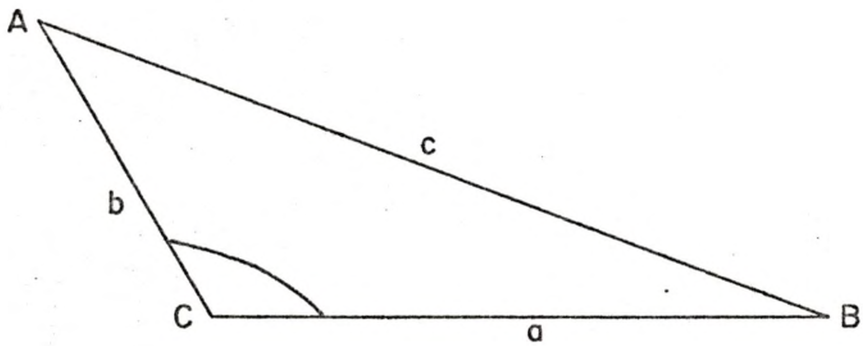
Sine Law:

$$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$$

Cosine Law:

$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$c = \sqrt{a^2 + b^2 - 2ab \cos C}$$



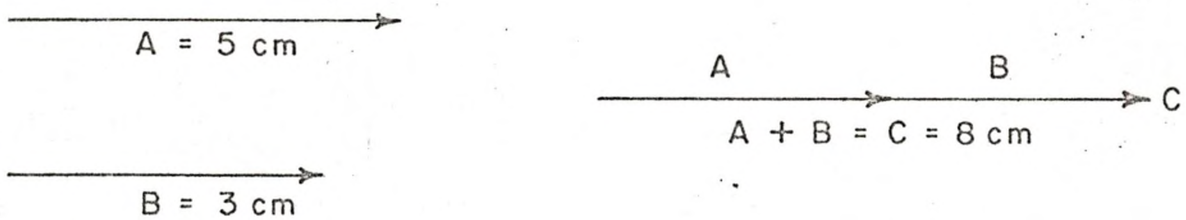
Vector Analysis Needs

Scalar and Vector Quantities Analyzed:
Large Group (Five Modules)

A quantity which can be expressed completely in appropriate units by a magnitude is a scalar quantity. A vector quantity requires both magnitude and direction for its complete description. Vector quantities should be identified whenever used throughout the study of physics. Because scalar quantities are self-explanatory, this review will deal mostly with the vector quantity and its functional operations.

Vectors Acting Along the Same Axis:
Parallel Vectors (One-Half Module)

In the study of physics, those quantities having both magnitude and direction are called vector quantities. If they act along a line in a given plane, they are referred to as parallel vectors. Parallel vectors acting in the same direction are added algebraically, while those acting in opposite directions are assigned negative components.



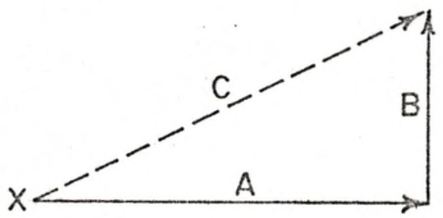
The graphical solution is to start with a common point of origin and then to add the vectors "tail-to-head." The combined length of the vectors gives the resultant or solution.

If vector B is negative, in the opposite direction to vector A, the graphic representation appears to be a subtractive process. Direction is frequently referred to as being either positive or negative. Such reference is purely arbitrary and cannot be assumed to lack variation.

Vectors Acting in a Coordinate System

Rectangular.--Two methods employed for the solution of vector problems are the analytical method and the graphic method. If the student has a limited background in mathematics, the graphic method should be used. Students with more mathematical training should be taught both ways.

Graphic method.--(a) Tail-to-head method (one-half module):

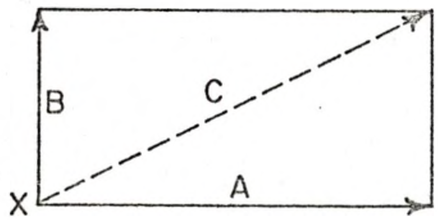


A + B = C

X = point of origin

(b) Parallelogram method (one module):

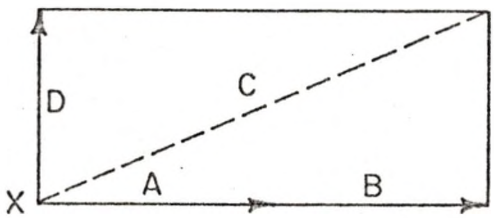
(1) Involving two vector quantities.



A + B = C

X = point of origin

(2) Involving three vector quantities (two in a line).

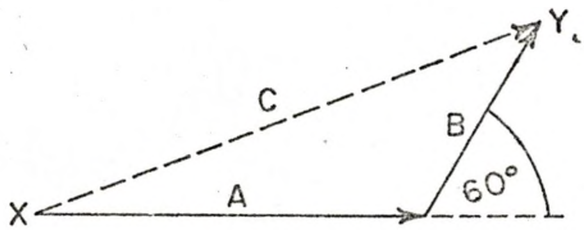


A + B + D = C

X = point of origin

Non-rectangular.--If two vector quantities act about a point X at a sixty degree (acute) angle to one another, the resultant may be found graphically as shown by the following diagrams.

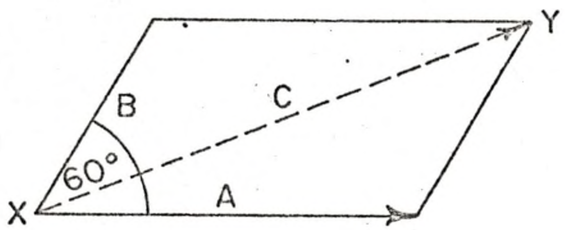
Graphic solutions.--(a) Tail-to-head method (one-half module):



A + B = C = XY

X = point of origin

(b) Parallelogram method (one-half module):

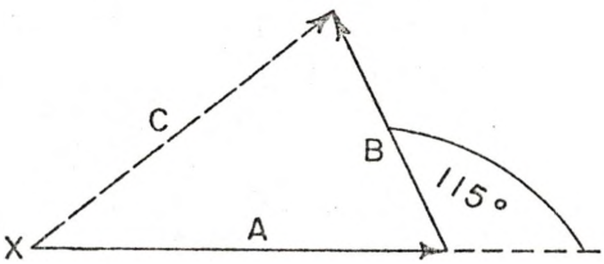


A + B = C = XY

X = point of origin

If vectors act about a point X at an obtuse angle to one another, the resultant may be found graphically in the following manner:

(a) Tail-to-head method (one-half module):

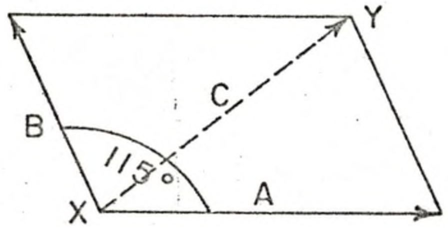


A + B = C = XY

X = point of origin

It is important to establish the proper direction of the resultant when using this method.

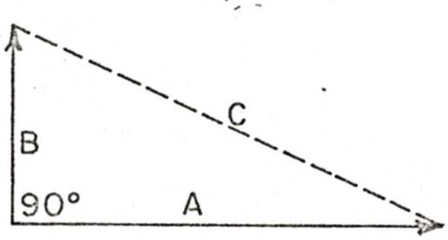
(b) Parallelogram method (one-half module):



$A + B = C = XY$

X = point of origin

Analytical solution (one module).--The composition of vectors acting at right angles requires use of the Pythagorean Theorem or the trigonometric functions of a right triangle.



$$C^2 = A^2 + B^2$$

$$C = (A^2 + B^2)^{1/2}$$

$$\tan \theta = B/A$$

All students should be taught how to find the square root of a number despite the availability of tables (one-half module).

Significant Figures and Scientific Notation: Large Group (Two Modules)

The following rules for determining the number of significant figures have been devised:

1. All nonzero digits are significant: 159.75 g contains five significant figures.
2. All zeros between two nonzero digits are significant: 108.005 m contains six significant figures.
3. Unless otherwise indicated, all zeros to the left of an understood decimal point but to the right of a nonzero digit are NOT significant: 202.000 mi contains three significant figures.
4. All zeros to the left of an expressed decimal point and to the right of a nonzero digit are significant: 202,000. miles contains six significant figures.
5. All zeros to the right of a decimal point but to the left of a nonzero digit are NOT significant: 0.000647 kg has three significant figures. The single zero conventionally placed to the left of the decimal point in such an expression is never significant.
6. All zeros to the right of a decimal point and to the right of a nonzero digit are significant: 0.07080 cm and 20.00 centimeters each contain four significant figures.[1]

Scientific Notation

Very large as well as very small numbers concern the physicist and scientific notations afford convenient means of dealing with them.

General: In scientific notation a number has the form $M \times 10^n$, where M is a number which is at least one but less than ten and n is a positive or negative integer.

Specific: To change a number into scientific notation:

1. Determine M by shifting the decimal point in the original number to the left or to the right until only one nonzero digit is to the left of it. Retain only significant figures.

---

[1] Charles E. Dull, H. Clark Metcalfe, and John E. Williams, Modern Physics (New York: Holt, Rinehart, and Winston, Inc., 1969), pp. 22-23.

2. Determine n by counting the number of places the decimal point has been shifted; if to the left, n is positive; if to the right, n is negative. Example: the speed of light expressed in scientific notation is 2.997928×10^{10} cm/sec.

Operations with Significant Figures (One Module)

The results of mathematical operations performed with measurements can be no more accurate than the original measurements themselves. Accordingly, certain precautions must be observed when performing such calculations so that a greater accuracy is not implied in the result than was originally obtained in the measurements.

1. Addition and subtraction. Suppose we must find the sum of the following measurements: 2.6 m, 12.57 m, and 0.395 m. Since the first measurement is uncertain in the "tenths" place, the sum should not be expressed more accurately than to tenths of a meter. Accordingly, we first round off all measurements so that the right-most column of digits is the only one containing uncertain digits; here, we round to tenths. Thus 12.57 m rounds to 12.6 m and 0.395 m rounds to 0.4 m. Then adding: 2.6 m, 12.6 m, 0.4 m = 15.6 m.
   Note: The procedure for rounding off states that if the first digit to be dropped in rounding is 4 or less, the preceding digit is not changed; if it is 6 or more, the preceding digit is raised by 1. If the digits to be dropped in rounding are only 5 or 5 followed by zeros, the preceding number, if even, is not changed but, if odd, is raised by 1. If the digits to be dropped in rounding are 5 followed by digits other than zeros, the preceding digit is raised by 1.
2. Multiplication and division. A block has the following dimensions: 15.42 cm long, 5.53 cm wide, and 2.70 cm high. Find the volume.
   15.42 cm x 5.53 cm = 85.2726 cm^2, however (a) the last significant figure in a number measurement is uncertain; (b) the product of any number by an

uncertain digit is also uncertain; and (c) only one uncertain digit is retained in any computation. The product becomes 85.3 cm^2.
Then 85.3 cm^2 x 2.70 cm = 230.310 cm^3, but the digits 0.310 are uncertain, so the volume expressed to the proper number of significant figures is 230. cm^3.[2]

Slide Rule

Basic Operations of the Slide Rule: Small Group (Four Modules)

It is suggested that the instructor or a proficient student use the large demonstration slide rule to explain the basic operations of:

1. Multiplication
2. Division
3. Extraction of roots
4. Raising numbers to the various powers

Practice in the operation should be accomplished with student help where groups do not exceed five persons.

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[2] *Ibid.*, pp. 23-24.

Closure Activities

Evaluation by testing would be common but it is advised that students be allowed to work in teams and that the average score of the total membership be the score of each member. Final evaluation should not be made until the students have used the materials in the corresponding units within the text.

Bibliography

Textbooks

Allendoerfer, Carl B., and Oakley, C. O. Fundamentals of Freshman Mathematics. New York: McGraw-Hill Book Company, Inc., 1959.

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Fehr, Howard F., and Carnahan, Walter H. Geometry. Boston: D. C. Heath and Company, 1961.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Reference Books

Beiser, Arthur. The Mainstream of Physics. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1962.

Castka, Joseph, and Lefler, R. Physics Problems. New York: Holt, Rinehart, and Winston, 1961.

Fehr, H. Secondary Mathematics--A Functional Approach for Teachers. Boston: D. C. Heath and Company, 1951.

Milne, William E., and Davis, David R. Introductory College Mathematics. Boston: Ginn-Blaisdell Company, 1962.

Mosteller, Frederick; Rourke, Robert E. K.; and Thomas, George B., Jr. Probability: A First Course. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1961.

Periodicals

ican Institute of Physics. Physics in Your High School. New York: McGraw-Hill Book Company, Inc., 1960.

Audio-Visual Aids

Vector Kinematics. PSSC 0109, 16 min., B & W.

Vectors. PSSC 0108, 27 min., B & W.

UNIT II

MECHANICS

Introductory Note

Mechanics is that branch of physics dealing with the effect of forces on bodies. It is usually subdivided into three areas. Statics is that branch of mechanics that deals with objects at rest or forces that balance each other. Kinetics deals with the effects of forces in causing or changing the motion of objects. Kinematics deals with the characteristics of different kinds of pure motion, without reference to mass or to the causes of motion. It can be seen that the term dynamics which deals with the action of force on bodies either in motion or at rest also includes statics, kinetics, and kinematics.

Unit Objectives

1. To study those factors that make physics an exact science.
2. To understand the practicality of the basic principles of motion.
3. To become knowledgeable regarding the scientific principles governing machines.
4. To ascertain the relationship between matter and energy.
5. To develop an understanding of composition and resolution of physical forces.
6. To observe and measure forces and relate them to the greater forces that control the motions of the planets.
7. To stimulate thought regarding the principle of conservation of mass, energy, and momentum.
8. To observe and experiment with the laws governing circular and rotary motion.
9. To develop a knowledge of how to achieve a balance of forces.
10. To demonstrate that large resistances can be overcome with small forces.

Suggested Outline for Presentation

I. Kinematics and Statics
   A. Motion--a continuing change of place or position
      1. Linear motion--motion in a straight line
      2. Rotary motion--motion about an axis
   B. Speed--rate of motion without reference to direction
   C. Velocity--rate of motion in a particular direction
   D. Velocity vectors
      1. Vectors and scalars
      2. Vector nature of velocity
      3. Addition and subtraction of velocity vectors
         a) Graphic method--composition and resolution
         b) Mathematical method--composition and resolution
   E. Acceleration--the rate of change of velocity
      1. $a = \frac{\Delta v}{\Delta t}$, where Δv is the change in velocity; Δt is the change in time
      2. Uniformly accelerated motion
      3. Decelerated motion
      4. Variable motion
   F. Statics
      1. Composition of forces
      2. Resolution of forces

II. Newton's Laws of Motion
   A. Newton's First Law of Motion: A body continues in its state of rest or uniform motion unless an unbalanced force acts on it
      1. Inertia--the property of matter which requires that a force be exerted on a body to accelerate it
      2. Mass--one measure of the inertia of a body
   B. Newton's Second Law of Motion: The acceleration of a body is directly proportional to the force exerted on the body, is inversely proportional to the mass of the body, and is in the same direction as the force
      1. Units of force--dyne, newton (nt), and pound (lb)
      2. Units of mass--gram (g), kilogram (kg), and slug
      3. Basic formula--$F = kma$
      4. Impulse $= F \cdot \Delta t = m \cdot \Delta v =$ momentum Δ
   C. Newton's Third Law of Motion: Whenever one body exerts a force upon a second body, the second exerts an equal and opposite force upon the first--for every action there is an equal and opposite reaction
      1. Mass $\cdot$ velocity = momentum
      2. Conservation of momentum

III. Newton's Law of Universal Gravitation: Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers

A. Basic formula: $F = \frac{G m_1 m_2}{s^2}$

B. Weight--the force that gravity exerts on the object: $W = mg$

C. Derive and solve for the mass of the earth

IV. Law of conservation of momentum

V. Law of conservation of energy (clarify all terms)

A. Kinetic and potential energy

B. Work as a measure of energy transfer

C. Power

VI. Circular motion--motion of an object along a curved path of constant radius

A. Centripetal acceleration

B. Centripetal force

VII. Rotary motion--motion of a body turning about an axis

A. Angular velocity

B. Angular acceleration

C. Moment of inertia

D. Angular momentum

E. Precession

VIII. General

A. Center of mass and gravity

B. Friction

C. Machines and mechanical advantages

Procedural Activities

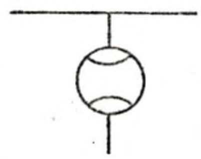
Motivational Techniques (Two Modules)

The instructor should perform a demonstration experiment that will attract the attention of the students and stimulate their interest in the topic.

Objective: To illustrate the law of inertia.

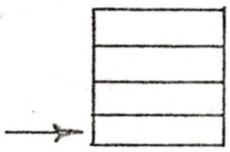
Materials: Inertia ball and string; card and pedestal; several hardwood blocks (smooth finish).

Procedure: Suspend the inertia ball as shown in the sketch. Pull gently but firmly on the lower string.



Second, place a ball on a card and balance on a pedestal as shown in the sketch. Snap the card by using the spring apparatus.

Third, stack several hardwood blocks as sketched. Strike the lowest block a sharp blow.



Observations: When the string is pulled gently, it breaks at a point above the ball, but when it is jerked the string breaks below the inertia ball. Second demonstration: When the spring strikes the card a sharp blow, the card sails from beneath the ball. The ball drops into the cup at the top of the pedestal. Third demonstration: The same type of action-reaction occurs as in two.

Conclusions: Gentle pulling adds your force to that exerted by the inertial ball, so the string breaks above. However, if the string is jerked the inertia of the ball must be overcome and the string breaks below the ball. Second demonstration: The force of the released spring strikes the card but not the ball resting upon it. The inertia of the card is overcome but not the inertia of the ball. Friction between the ball and card is negligible. Third demonstration: Same explanation as for two.

There are many demonstration experiments that can be done by the instructor, such as the step-on cart for action-reaction, use of the collision ball apparatus, projectile cart, gyroscopes, and coin and feather-tube experiment for falling bodies.

Students and teachers should keep a well-dressed bulletin board. Every effort should be made to relate the text materials with current events in science and exploration.

Interest Development

Kinematics: Large Group (One Module)

Kinematics is concerned with the concepts of speed, position, and time. It describes motion without taking into account what it is that moves or what causes the motion. Any moving body can be used to illustrate acceleration and velocity and both can be either positive or negative.

Laboratory (One Module)

The use of the straight path, the curved path and the cycloid path to discover the relationships between the velocity, time and momentum of a ball on each path.

Laboratory (One-Half Module)

Individual trial and observation of the feather and coin in an evacuated tube.

Student participation is assumed for all laboratory work, because of the nature of the experiments designed. The laboratories should be kept open during the entire school day so that students might use them for independent study.

As a basic guide in the development of vectors, the PSSC Physics text, pages 74-92, presents a vivid explanation. The instructor should show the development by using the blackboard, drawings and graphs in a large group, general explanation. Then students should solve problems in small groups.

Dynamics: Large Group (Four Modules)

Dynamics includes the causes of motion, what is moving, and how its nature affects the motion. The pushes and pulls which cause, resist, and determine motions must be taken into account as well. A large group, one module explanation for each of the four laws should be planned.

Newton's First Law of Motion (Law of Inertia) has been stated previously. The important consideration for interest development pertains to the demonstrations and student experiments to be completed. It is suggested that the students be challenged to design an original demonstration. The student ideas should be discussed briefly within the small groups and the best ideas should be presented to the large group meeting by the student.

Small group topics for discussion might include the great force exerted on the astronauts as they leave the earth's gravitational field on a journey to the moon, the operation of a loop-o-plane, a fast ascending elevator, or the effect on standing passengers when a bus halts abruptly.

Newton's Second Law of Motion is applicable in baseball--pitching,

...tching, batting, and sliding. It also applies to track, football, ...nnis, golf, and in fact, to all sports.

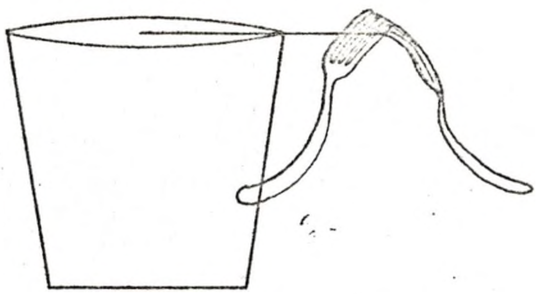
...boratory

Force tables should be used for analyzing composition and resolu...on of force vectors. Equilibrium of parallel forces should be studied ...d these experiments should be conducted individually. The study of ...lling and sliding friction can be done at this time. Bulletin materials ...ould be selected to exemplify various operations, processes and ...ations of Newton's Laws, but should leave their determination to the ...udents.

Newton's Third Law (Action-Reaction) could be related to the use of seat belts, firing a bazooka, rocketry, rowing a boat, jet propulsion, and the walk-on-cart.

Newton's Law of Gravitation (Force of Attraction) can readily be related to the throwing a shot-put, discus, or javelin in field events. The force between people and the earth can be discussed. The bulging shape of the earth and its affect on the force of gravitation; including the earth in its orbit, and the tides and their relation to sun, moon and earth rotation make very interesting topics for small group discussion.

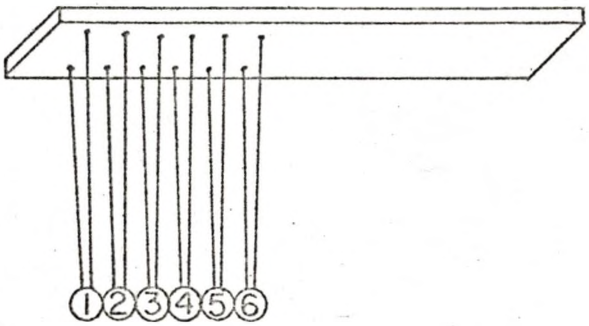
The concepts of center of mass and center of gravity should be considered at this time. The center of mass is defined as that point at which all the mass of an object is considered to be concentrated. The center of gravity is that point at which all of the weight of a body is considered to be concentrated. The rocking-horse apparatus, spoon-fork-glass and toothpick apparatus, and problems such as seeking the weight of a fish that could be supported by a fishing pole with a center of gravity that can be determined. Perhaps the most effective demonstration is the apparatus I have chosen to call the spoon-fork-glass and toothpick.



Spoon tip is pushed into the fork tines. Combination is then balanced on a toothpick supported by the edge of a water glass.

If a match is used to ignite both ends of the toothpick, the toothpick will burn to the edge of the glass on the one end and to the fork tine on the other end. This leaves only a tiny point of balance.

The Law of Conservation of Momentum states that the total momentum before impact is equal to the total momentum after impact. The "collision ball" apparatus illustrated on the next page may be used to demonstrate this phenomena. The laboratory manual presents an experiment that should be done by each student.



The balls must be adjusted carefully so that they strike each other squarely. If ball one is pulled to the side and allowed to collide with the other five balls, the impact will cause ball six to swing from the pack. If balls one and two are pulled to the side and allowed to collide with the remaining four, the impact will drive balls five and six from the pack. It is interesting to note what action-reaction takes place when four balls are allowed to collide with the two that remain.

Potential energy should be discussed. It is stored energy or energy possessed by a body by virtue of its position or configuration. The potential energy possessed by a body cannot be measured directly. It can be measured indirectly by conversion to some form of kinetic energy.

Laboratory (Two Modules)

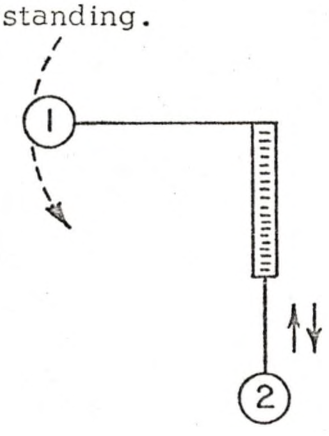
Do the experiments on conservation of energy that can be found in the manual.

Traditionally, the six simple machines are the lever, pulley, wheel and axle, inclined plane, screw, and the wedge. Essentially there are probably only two groups of simple machines, levers and inclined planes. Models can be used to advantage, but if they are not available most classrooms have several examples--actual machines afford more complex understandings.

Laboratory (Four Modules)

Do the experiments in the manual pertaining to the simple machines and their mechanical advantages. The accuracy will be determined by the measuring tools available. The simple machine experiments should take about four modules, but slower students can utilize some independent study time for completion.

When angular momentum is studied, the device pictured will enhance understanding.

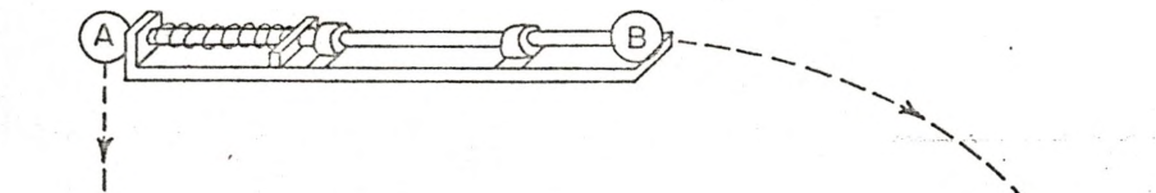


Grasp the hollow tube and cause the rubber ball (one) to rotate. If the velocity of rotation becomes great enough the rubber ball will move outward and lift the metal ball (two).

Ball (one) is sponge rubber while ball (two) is brass or steel. The two balls are connected by a strong cord that passes through a hollow tube. The implications can be discovered by the students.

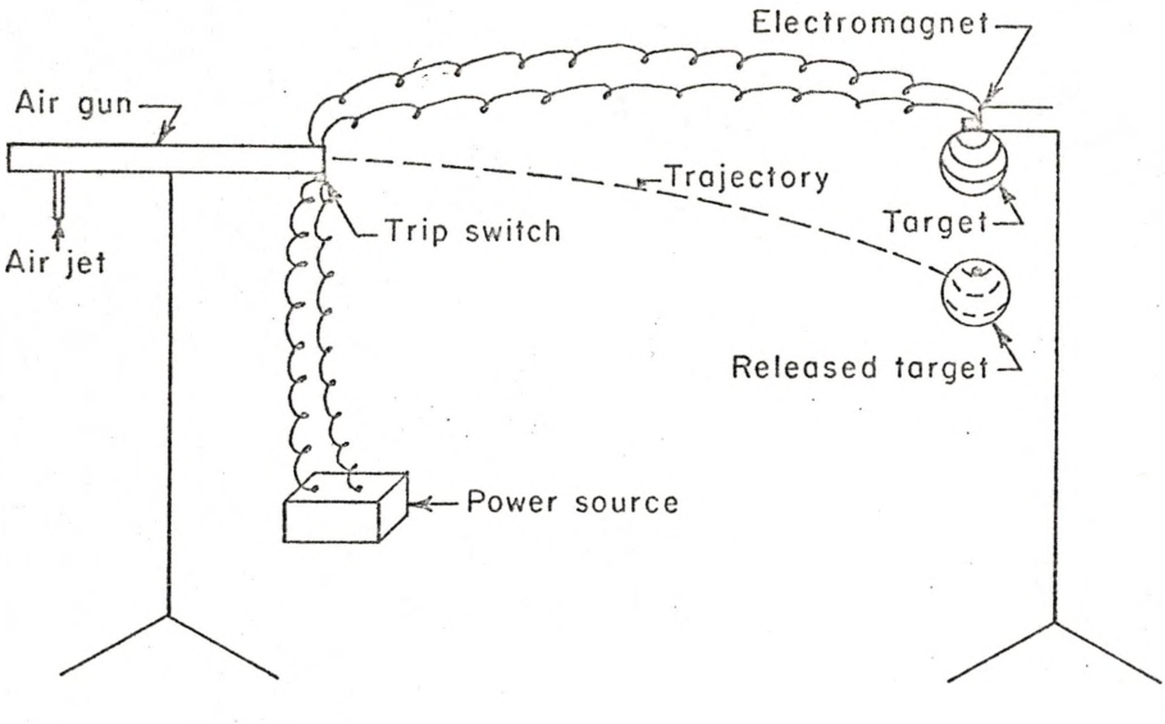
An electrically powered gyroscope can be used to demonstrate gyroscopic stability and angular momentum. The ideal model has angular vectors and weight that can be adjusted. Stability can be shown by the use of a weighted bicycle wheel and a stool that rotates freely (standing platform made from a car rim and axle is best). An interesting demonstration requires a student to stand on a rotating platform holding weights in his outstretched hands. Lowering the weights to his sides produces a phenomena for student consideration in small group discussion. This demonstration should be done as part of large group instruction (one module).

Projectiles and trajectories may be studied by using the apparatus for Newton's Second Law of Motion, but the air gun and monkey give a better demonstration. The demonstration and general explanation should be done with the large group, then discussed in small group sessions and carried into the laboratory for independent study. The time allocation breakdown is: large group (one module), small group (one module), and independent study (two modules). The second law of motion apparatus and the air gun and monkey apparatus are diagrammed:



Ball A reaches position A_1 at the same instant that ball B reaches position B_1, after the spring has been released.

If the air gun and monkey apparatus are available, it much more effectively demonstrates projectile trajectories.



When the projectile leaves the gun barrel, it trips a switch and releases the monkey target. The target is always struck if the gun was accurately aimed and fired horizontally. The gun is at the same initial elevation as the target (one module).

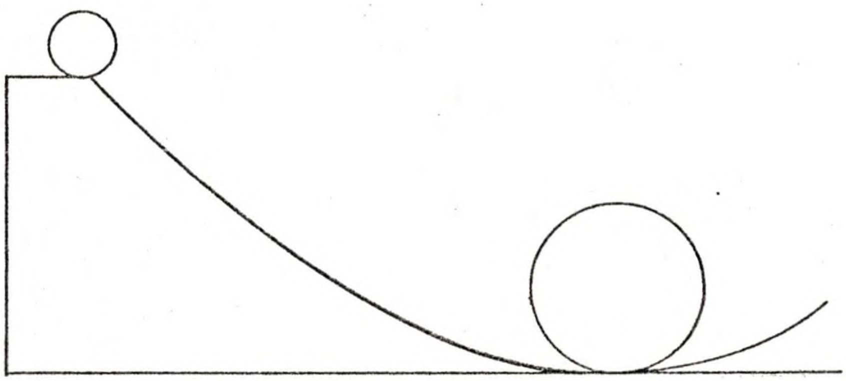
Laboratory (Two Modules)

The experiment on centripetal force completes the study of the unit.

Closure Activities

An experiment with a complex machine such as a train of gears with a wheel and axle attachment has reinforcement value (one module of independent study).

Students can experiment with the elevation needed above a loop for a ball to roll down the plane and completely around. Then, they can relate the elevation to the loop radius (one module of independent study).



Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey. E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

Reference Books

Andrade, E. N. da C. Sir Issac Newton. Garden City, New York: Doubleday and Company, Inc., 1954.

Battan, Louis J. The Nature of Violent Storms. Garden City, New York: Doubleday and Company, Inc., 1961.

Bondi, Herman. The Universe at Large. Garden City, New York: Doubleday and Company, Inc., 1960.

Cohen, I. Bernard. The Birth of a New Physics. Garden City, New York: Doubleday and Company, Inc., 1960.

Gamow, George. Gravity. Garden City, New York: Doubleday and Company, Inc., 1962.

Hughes, Donald J. The Neutron Story. Garden City, New York: Doubleday and Company, Inc., 1959.

Koestler, Arthur. The Watershed. Garden City, New York: Doubleday and Company, Inc., 1960.

Weisskopf, Victor F. Knowledge and Wonder: The Natural World as Man Knows It. Garden City, New York: Doubleday and Company, Inc., 1962.

Periodicals

The Physics Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Science News Letter. Science Service, 1719 N. Street, N.W., Washington, D. C.

The Science Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Scientific American. 2 West Forty-fifth Street, New York.

Senior Science. Science World, 900 Sylvan Avenue, Englewood Cliffs, New Jersey.

Audio-Visual Aids

Conservation and Energy. PSSC 0313, 27 min., B & W.

Deflecting Forces. PSSC 0305, 30 min., B & W.

Energy and Its Transformation. 11 min., color, Resource Center.

Energy and Work. PSSC 0311, 28 min., B & W, Resource Center.

Forces. PSSC 0301, 23 min., B & W, Resource Center.

Frames of Reference. PSSC 0307, 28 min., B & W, Resource Center.

Free Fall and Projectile Motion. PSSC 0304, 27 min., B & W, Resource Center.

Gravity, Weight and Weightlessness. 11 min., color, Resource Center.

Inertia. PSSC 0302, 26 min., B & W, Resource Center.

Periodic Motion. PSSC 0306, 33 min., B & W, Resource Center.

Simple Machines. 11 min., B & W, Resource Center.

Straight Line Kinematics. PSSC 0107, 34 min., B & W.

Universal Gravitation. PSSC 0309, 31 min., B & W.

UNIT III

MATTER AND ITS PROPERTIES

Introductory Note

The properties of fluid bodies whose shape can be changed by the action of forces or stresses, will be studied in this unit. The kinetic-molecular theory will form the basis for much of the explanation of the states of matter under consideration.

Unit Objectives

1. To relate the assumption that pressure and diffusion cause molecules to be in constant but random motion.
2. To explain cohesive and adhesive forces as the attraction of one molecule for another when the two are relatively close together.
3. To relate distortion and restoration forces.
4. To demonstrate transmission of pressure by liquids.
5. To study buoyancy and to discuss some of its practical applications.
6. To discuss the similar and dissimilar properties of gases and liquids.
7. To uncover the unique aspects of fluids.

Note: Although it is not impossible to be effective as a teacher where equipment is very limited, it has been demonstrated that interest, retention, continued pursuit of study in the sciences, as well as thorough understanding are all closely associated with fine laboratory facilities and equipment.

Suggested Outline for Presentation

I. The Kinetic Theory
   A. Matter is composed of very tiny particles called molecules
   B. Molecules are in constant motion
   C. Molecules obey Newton's laws of motion

II. Forces Acting Between Molecules
   A. Molecular attraction
      1. In solids
      2. In liquids
      3. In gases
   B. Close proximity repulsion

III. Mass Density and Weight Density

IV. The Physics of the Solid State
   A. Geometry of crystals
   B. Amorphous matter

V. The Physics of Liquids and Gases

VI. Diffusion, Cohesion, Adhesion, Surface Tension, Capillarity

VII. Tensile Strength, Ductility, and Malleability

VIII. Elasticity
   A. Extension, compression, torsion, and flexion
   B. Elastic collisions (quartz balls)
   C. Stress = F/A
   D. Strain = $\Delta l/l$
   E. Hooke's Law (Young's Elastic Modulus), $Y = \frac{F/A}{\Delta l/l} = \frac{Fl}{\Delta lA}$

      F = force
      A = area
      Δl = change in length
      l = length

IX. Fluid Pressure
   A. Liquid pressure
   B. Gaseous pressure
      1. Torricelli
      2. Magdeburg
      3. Boyle

C. Measuring the pressure of fluids
   1. Bourdon gauge and monometers
   2. Aneroid and mercurial barometers
   3. Standards of pressure
D. Fluids in motion
   1. Pascal's principle
   2. Venturi meter
   3. Bernoulli's principle
E. Archimedes' principle

Procedural Activities

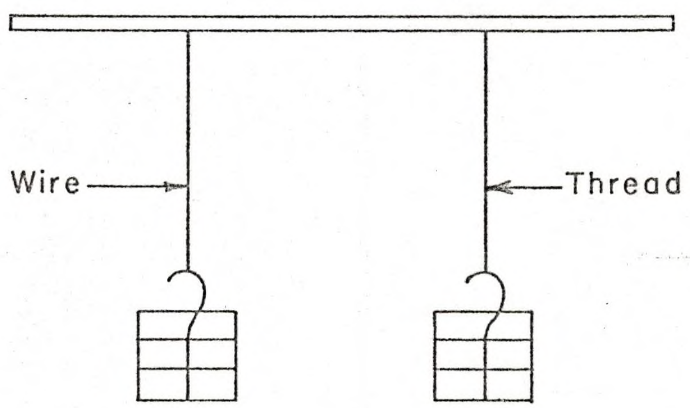
Motivational Technique: Large Group (Two Modules)

Interest can be generated by several teacher demonstrations that pertain to the properties of matter. In an opening large group presentation, students should become acquainted with the meanings of terms such as: (1) tenacity, (2) ductility, (3) malleability, (4) elasticity, (5) adhesion, (6) cohesion, (7) viscosity, and (8) surface tension.

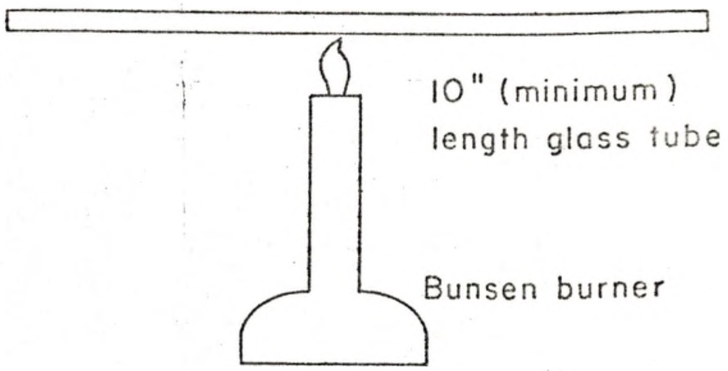
Objectives: To demonstrate (1) tenacity, (2) ductility, (3) elasticity, (4) surface tension, (5) cohesion, and (6) adhesion.

Materials: Small gauge steel wire and cotton thread; glass tubing; high bounce "rubber" ball and "nutty putty"; surface tension apparatus; polished glass cohesion plates; an adhesion disk; and a mounted platform balance. Note: These demonstrations should be displayed for close observation by the small groups.

Procedure: Tenacity--set up equipment as shown by the sketch. Proceed to hang weights on both until the less tenacious breaks.

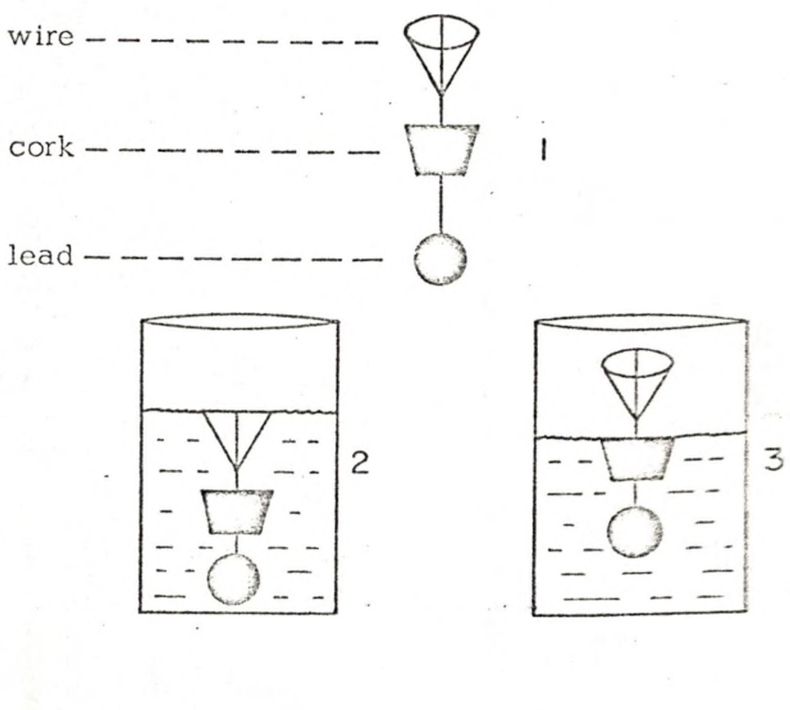


Ductility--heat a glass tube until white hot. When the instructor indicates, an assistant is asked to take one end of the tube and run with it. An exceedingly fine glass thread will be the result.

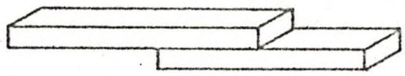


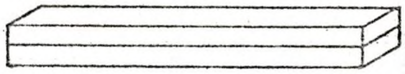
Elasticity--use a high bounce "rubber" ball, quartz balls, or "nutty putty." Balls will bounce higher initially and continue to bounce for a longer period of time than conventional balls.

Surface tension--refer to the sketches. Before submersion (1), during submersion (2), and detergent added (3).



Cohesion--highly polished glass plates are made to slide together.

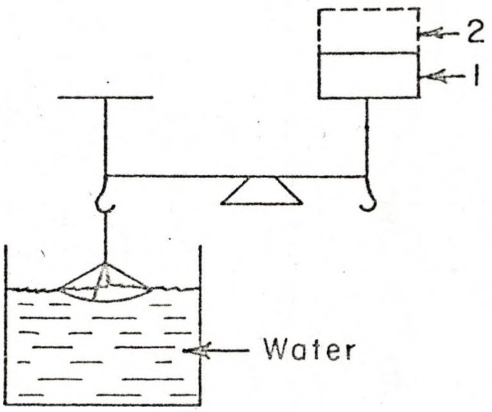

plates



tightly bound

Very difficult to pull the plates apart.

Adhesion--an adhesion disk is tied to the hook on the base of a mounted platform balance. Weights are used to carefully put the system in balance before and after as shown. (1) Weight needed before disk touches water; (2) weight needed to lift plate free of water surface after touching.



Observations: Tenacity, cotton thread breaks first. Ductility, a very fine glass thread results. Elasticity, all three return to virtually the original position on the first bounce. Surface tension, apparatus remains submerged until the detergent is added. Cohesion, glass plates seem cemented together. Adhesion, greater weight can be placed on the balance when the disk is in contact with water.

Conclusions: Tenacity, wire is of much greater tensile strength. Ductility, molten glass is very ductile. Elasticity, these materials have great elasticity. Surface tension, surface tension is a force that can overcome the buoyant force. Cohesion, some substances are strongly attracting to molecules like their own when brought close together. Adhesion, the attraction between unlike materials such as water for glass is measurable.

Each demonstration should become a part of the small group discussion. There are many other effective demonstrations that may be used to supplement those suggested.

Films to be Shown: Large Group (Two Modules)

1. Application to Pascal's Law, Parts I and II.
2. Molecular Theory of Matter.

Interest Development

The Kinetic Theory

The term kinetic comes from the Greek word kinetikos which means to move. By definition it means of or having to do with motion; caused by or resulting from motion. In the study of physics, we will frequently come in contact with kinetic energy, kinetic heat, kinetic theory of gases, kinetic theory of heat, kinetic theory of matter, etc.

A theory is an explanation based on observation and reasoning. It, also, has Greek roots in theoria (a looking at) and theorein (to consider).

Kinetic theory then asks the student to look, consider, think and reason about motion. It is an explanation that has been tested and at least partially confirmed as a general principle explaining a large number of related facts.

Forces Acting Between Molecules (Two Modules)

It can be observed that liquids and solids are not easily compressed. In fact, when molecules in these states of matter are forced closer together than their normal spacing, they repel each other. To increase the compressing force simply causes the repulsive force to increase. The force of attraction between molecules is slight when the distance separating them is relatively great, but it increases as the molecules come closer together, reaches a maximum, and then moves to zero at the normal molecular spacing. If the space is further diminished, the force becomes one of repulsion which increases very rapidly as the molecules are pushed closer together.

Mass Density and Weight Density

It should be noted that the mass of a body is assumed to be a constant. Mass density would not vary as the unit is taken from one elevation to another or even if the move carried it outside of the earth's gravity field. Weight, however, is dependent upon gravity and would vary greatly as the unit moves away from and toward the earth's center of gravity.

The Physics of the Solid State

Crystallography deals with the form, structure, and properties of crystals. The presentation pertaining to crystals in the PSSC textbook pages 142-144 is well done. It is suggested that some students work with the development of crystals as an independent study. Cleavage planes, lines of cleavage and geometric design can be shown for some crystals. The student should be made aware that crystalline solids may consist of atomic, ionic, molecular, or macromolecular crystals.

Diffusion, Cohesion, Adhesion, Surface Tension, Capillarity (Two Modules)

Solids, liquids and gases diffuse. If a gold plate and a lead plate are in close contact for a period of months it can be seen that they diffuse into each other. This demonstrates solid diffusion. Liquids and gases can be shown to diffuse more readily. The use of copper sulfate solution and pure water makes a good demonstration for liquid diffusion. Students may be given "diffusion" as an independent study unit.

Cohesion, adhesion, surface tension, and capillarity should be topics for small group discussion and demonstration. Why does a razor blade float on water? What causes the water level in capilliary tubes to vary? Why does a camphor boat become self-propelled when placed on water? Why do polished glass plates stick together? What happens when a match stick that has been drawn through the hair is touched to the surface of water on which pepper has been sprinkled? Why does a small paper boat move about when placed on water after a piece of camphor has been fastened on its stern?

Tensile Strength, Ductility, and Malleability

These were used as motivational activities, but they should be taken to the small group discussion periods.

Elasticity (One Module)

Elasticity is the property of matter that causes it to return to its original shape when a distorting force has been removed. The small group unit should be subdivided into four equal parts so that demonstrations of extension, compression, torsion, and flexion can be set up, preferably by interested students. Each sub-unit should be given time to view and discuss the kinds of elasticity.

Laboratory: Hooke's Law experiment (Young's Modulus).

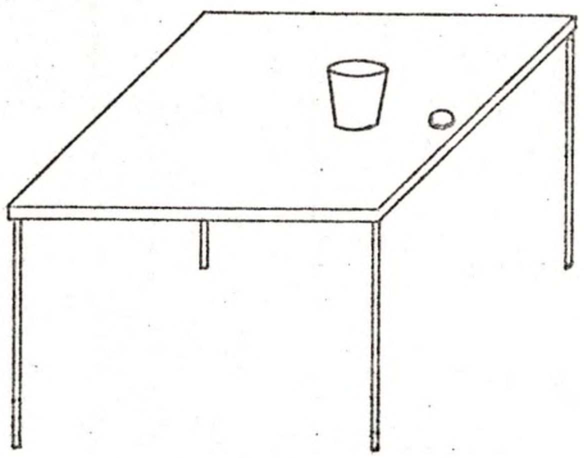
Fluid Pressure (Two Modules)

Pressure within liquids and gases when in motion and at rest is to be considered in this unit.

Demonstration of the Magdeburg
Hemispheres and Guinea-and-Feather
Apparatus: Large Group (One Module)

Laboratory: Experiment with Pascal's vases (one module); experiment involving Archimedes' principle (one module); experiment with specific gravity: hydrometers, pycnometer and loss of weight methods (one module); experiment with Boyle's Law (one module); demonstration of the hydraulic press and its operation: large group (one module); discussion of practical applications of the press: small group (one module); and demonstrations of Bernoulli's Principle: large group (one module).

1. Hold a strip of paper against the chin just below the lower lip. Blow a stream of air directly outward.
2. Cut a card about three inches square (from the back of a tablet). Push a pin through the card at a point near the card's center. Place the pin in the opening through a thread spool. Hold the card on one end of the spool and blow hard in the other end. Release card when blowing.
3. Suspend two ping-pong balls with threads so they hang about an inch apart. Blow a jet stream of air between the two balls.
4. Float a ping-pong ball in an air stream from an air pump. Change the angle of the air stream so that the hand can be waved directly below the ball. A stream of water can be used also.
5. Make a dime jump from a table top into a cup or water glass.



Place lips firmly against the table edge and build pressure by blowing. Tip the head back so that the air shoots up and over the dime. When adjusted well the dime will jump into the air and land in glass. Practice needed.

This is perhaps the most effective demonstration. Explain briefly about the density of silver in relation to water and the density of water in relation to air so that the students will understand the full significance of the "lifting force" exerted by an air stream of great velocity. The air moving with a great velocity over the upper surface of the dime reduces air pressure above the dime.

Discussion of Each Demonstration
Experiment: Small Group (One Module)

Other topics for small group discussion might include: How does a submarine operate? What is the purpose of the Plimsoll mark on a ship? How does a Cartesian diver function? What is meant by the term "four level ocean"?

Closure Activities

A visit to a wind tunnel used for testing wing design is of much interest. Student interest reports can be prepared on craft lighter than air such as dirigibles or on diving bells, caisons, and scuba equipment. The study of barometers, altimeters, Venturi tubes, changes of state (making a mercury hammer if liquid air is available), can be included.

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

Reference Books

Boys, Sir Charles Vernon. Soap Bubbles. Garden City, New York: Doubleday and Company, Inc., 1959.

Davis, Kenneth S., and Day, John A. Water: The Mirror of Science. Garden City, New York: Doubleday and Company, Inc., 1961.

Hughes, Donald J. The Neutron Story. Garden City, New York: Doubleday and Company, Inc., 1959.

MacDonald, D. K. C. Near Zero: The Physics of Low Temperature. Garden City, New York: Doubleday and Company, Inc., 1961.

Shapiro, Asher H. Shape and Flow: The Fluid Dynamics of Drag. Garden City, New York: Doubleday and Company, Inc., 1961.

Weisskopf, Victor F. Knowledge and Wonder: The Natural World as Man Knows It. Garden City, New York: Doubleday and Company, Inc., 1962.

Note: Manuals and workbooks are readily available for all textbooks mentioned in the listing.

Periodicals

The Physics Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Science and Math Weekly. American Education Publications, 1250 Fairwood Avenue, Columbus, Ohio.

Science News Letter. Science Service, 1719 N. Street, N.W., Washington, D. C.

The Science Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Scientific American. 2 West Forty-Fifth Street, New York.

Senior Science. Science World, 900 Sylvan Avenue, Englewood Cliffs, New Jersey.

Audio-Visual Aids

Application of Pascal's Law, Part I, 13 min., B & W, Resource Center.

Application of Pascal's Law, Part II, 15 min., B & W, Resource Center.

Molecular Theory of Matter, 11 min., B & W, Resource Center.

If these materials are not available to the school, it is highly recommended that efforts be made to make them available. A library of films and filmstrips must be part of the school facilities in all areas of instruction.

UNIT IV

HEAT

Introductory Note

If there were no heat, there would be no light. If there were no heat, there could be no life as we now consider it. Man's ability to control and produce heat is an essential factor in the development of society.

Heat may be produced in many ways such as: chemical action, friction, collision or impact, compression, nuclear reaction, and electricity. Almost all of the energy utilized on the earth comes either directly or indirectly from the SUN.

We will study the work of Benjamin Thompson (Count Rumford), William Thomson (Lord Kelvin), J. P. Joule, Henry Rowland, and others. These men have given us the basic understanding of heat that we now possess.

Unit Objectives

1. To establish heat as a form of energy that can be measured.
2. To develop quantitative thinking regarding heat, thermal energy, and temperature.
3. To understand the relationships between the forms of energy such as heat and mechanical energy.
4. To discuss heat transfer by conduction, convection, and radiation.

Suggested Outline for Presentation

I. Conservation of Energy
   A. Interrelatedness of all forms of energy by means of the molecular theory
   B. Energy cycle

II. Heat and Temperature
   A. Nature and sources of heat energy
   B. Temperature and temperature scales
   C. Thermal energy
   D. Specific heat

III. Heat Transfer
   A. Conduction, convection, and radiation
   B. Black body radiation

IV. Expansion
   A. Solid expansion
      1. Coefficient of linear expansion
      2. Coefficient of volume expansion
   B. Liquid expansión--only interested in volumetric expansion
   C. Gaseous expansion
      1. Change in molecular motion with temperature change
      2. Coefficient of expansion of gases

V. Charles' Law and Boyle's Law Combined
   A. Interrelatedness of pressure, volume and temperature
   B. Kelvin scale and absolute zero

VI. The General Gas Law and Avogadro

VII. Change of State
   A. Heat units--metric and English systems
   B. Heat of fusion, heat of vaporization, heat exchange

VIII. Laws of Thermodynamics
   A. Isothermal and adiabatic processes
   B. Carnot cycle
   C. Heat engines

Procedural Activities

Motivational Techniques

Films: Large Group (Two Modules)

There are three films that may be utilized to a great benefit by the class: Behavior of Gases, Thermodynamics, and Heat.

Demonstrations: Large Group (Two Modules)

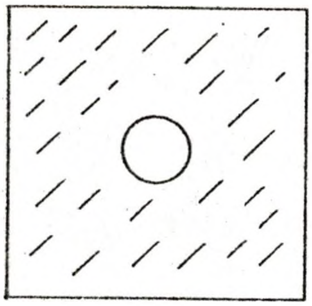
Graphically show how all forms of energy are related. This may be done effectively by using the overhead projector and prepared transparencies.

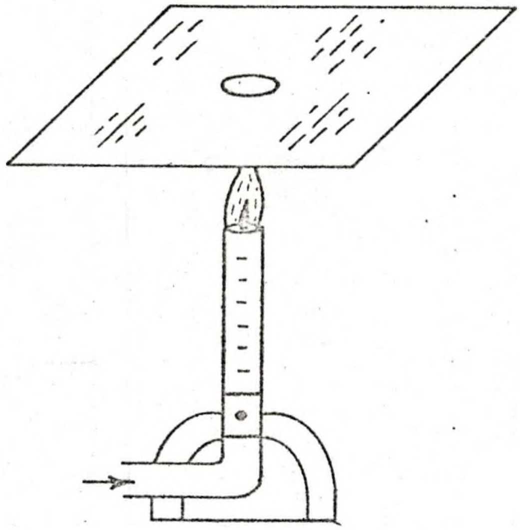
Show how the light energy of the sun can be converted into heat by the use of a solar reflector or a large convex lens.

Theorize regarding the changes that might evolve at extremes of temperature. Immerse an inflated toy balloon in a container with dry ice. Expose a weiner to dry ice, and quick freeze several other items.

Demonstrations: Small Group (Two Modules)

Demonstrate and then, discuss the effect of heating a metal plate that has a hole in its center. Will the hole become larger or smaller?





Interest Development

Conservation of Energy

All substances are assumed to be composed of small particles called molecules. The motion of these particles may be increased or diminished as energy is either absorbed or released. It is possible to measure the heat energy lost or received by the effect one body has upon another. The apparatus for a Joule experiment, to observe the conversion of mechanical energy into heat, may be used to demonstrate the interrelatedness of different forms of energy.

Heat and Temperature

The basic assumptions on which the kinetic theory of gases is established can effectively aid in the understanding of temperature. A quantitative description is of more value than a qualitative one but both should be utilized. The students should be made aware that a thermometer does not measure heat directly. A thermometer measures the expansion of a substance such as mercury in a fine bore tube caused by an increase in molecular activity.

Laboratory: Small Group (Two Modules)

Experiment: The method of mixtures.

Equipment: Calorimeter, centigrade thermometer, hypsometer, metal shot, burner, water, and an accurate balance.

Object: To determine the specific heat of a metal. Any lab manual will furnish the details.

Heat Transfer

If heat is molecular motion, it should be possible to demonstrate that substances vary as to the time required to activate the molecules.

Laboratory: Small Group (Two Modules)

The student should use the conductometer, convection of liquids apparatus, and the convection of gases apparatus. A heated metal ball may be used to demonstrate heating by radiation. The relative merits of different home heating systems should be discussed. Discuss the "black body."

Expansion

Expansion of solids, liquids and gases affords man one of his most perplexing phenomenon. Water freezing in the cracks of concrete destroys highways and buildings, but it is used to split rocks and granite blocks into the desired shapes and sizes. Industry spends millions of dollars in its efforts to control linear, volumetric, and area expansion.

Laboratory: Small Group (One Module)

Quickie experiments: Pulse glass, bimetallic strip, and the ball and ring apparatus.

Laboratory: Small Group (Two Modules)

Experiment: Expansion of a metal rod.

Equipment: Micrometer screw type expansion apparatus, thermometer, hypsometer, metal rod set.

Object: To determine the expansion of various metals within controlled temperature limits. Any lab manual may be used to furnish the details.

Combined Charles' and Boyle's Laws

The Kelvin scale of temperature, Charles' Law and the general gas law should also be discussed and explained mathematically.

Change of State

The state in which matter exists depends upon the heat energy content of the body. Change in state occurs only when heat is added or subtracted. For this work the student must understand the terms calorie and british thermal unit.

Laboratory: Small Group (Four Modules)

Experiment one: Heat of fusion.

Equipment: Calorimeter, thermometer, water and ice.

Object: To determine the heat of fusion of ice. Any lab manual may be used for details.

Experiment two: Heat of vaporization.

Equipment: Hypsometer, calorimeter, thermometer, and a burner to heat the water that was placed in the hypsometer.

Object: To determine the heat of vaporization of water vapor. Refer to a lab manual.

The Equivalence of Mechanical and Thermal Energy

Investigate the laws of thermodynamics, isothermal, and adiabatic processes. A student should be selected to present a lesson on the basic operations of the steam engine and internal combustion engine.

Laboratory: Independent Study

Students should have the opportunity to work with Joule's apparatus. This should be considered as a project rather than an assignment. After careful work has been done and the apparatus is fully understood the student(s) should report to the class and demonstrate how the apparatus works.

Closure Activities

It should be remembered that the test is only one necessary form of closure activity.

The demonstration cited below would provide a thought provoking closure activity and could be used as the basis for a written exam or for discussion.

Heat metallic cylinders in the same container to assure equal temperature. The cylinders should all be of the same size, but of different materials, such as copper, steel, brass, and aluminum. Place the heated cylinders on a paraffin block and note the degree of penetration into the block. Do the same thing with cylinders of the same metals whose masses have been made equal, keeping the base area of the cylinders equivalent.

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1959.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

Laboratory Guides

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

White, Harvey E. Laboratory Exercise for Physics. Princeton, New Jersey: D. Van Nostrand Company, 1959.

Audio-Visual Aids

Behavior of Gases. PSSC 0115, 15 min., B & W.

UNIT V

TYPES, PROPAGATION AND PROPERTIES OF WAVES

Introductory Note

Early in the study of physics, the student is made aware that transfer of matter requires energy, but that no energy is lost in the transfer. If matter is changed from one form or state to another, energy is absorbed or "released." When sound and light are studied, the student becomes acquainted with energy transfers which are not accompanied by a mass transfer.

Unit Objectives

1. To acquaint the student with the basic terminology used in wave description, the student needs a clear definition for such terms as: crest, trough, superposition, wave length, frequency, and amplitude, so that he can participate in the discussion of wave mechanics.
2. To develop an understanding of wave types as well as a proficiency in differentiating between the wave types under discussion.
3. To demonstrate and discuss the properties of transverse and longitudinal waves. The student should develop an appreciation for waves as a mode of energy transfer.
4. To propagate waves in a ripple tank, and show the interrelatedness of physical (water) waves to sound and electromagnetic waves.

Suggested Outline for Presentation

I. Energy Transfer By
   A. Bodily motion of masses of material
   B. The motion of particles
   C. Mechanical waves
   D. Electromagnetic waves

II. Wave Types
   A. Pulses
      1. Transverse
      2. Longitudinal
      3. Rarefaction
      4. Reflection
      5. Incident
   B. Mechanical
   C. Transverse
   D. Longitudinal
   E. Periodic
   F. Standing
   G. Electromagnetic

III. Characteristics of Waves
   A. Speed
   B. Phase
   C. Frequency
   D. Period
   E. Wavelength
   F. Amplitude

IV. Superposition
   A. Construction interference
   B. Destructive interference

V. Common Properties of Waves
   A. Rectilinear propagation
   B. Reflection
      1. Straight pulses
      2. Circular pulses
   C. Refraction
   D. Interference
   E. Diffraction

Procedural Activities

Motivational Techniques: Large Group (One Module)

Wave projection in a ripple tank using an adjustable phase generator may be used to build immediate interest. Resonance tubes, xylophones, resonance bars, tuning forks, torsion apparatus for studying waves, helical springs, Kundt's apparatus, resonance apparatus, interference plates, Galton's whistle, Savart's toothed wheel or disk, sonometers, and others, should be used for demonstrations in the large group. The demonstrations may be discussed in the small group situation and the physical phenomena explained. The large group instructor should do very little except demonstrate the equipment. He should not endeavor to provide explanations.

PSSC has an excellent film entitled Simple Waves that may be used for motivation of the large group. If this film is used it should be used in conjunction with one entitled Similarity in Wave Behavior, and three modules should be allocated for the combination.

Interest Development

Energy Transfer: Large Group (One Module)

As a project for independent study, an interested student might construct an apparatus for the controlled firing of carbon dioxide capsules. This student demonstration will furnish a fine example of energy transfer by the motion of material masses. Heating a brass rod at one end while touching the opposite end exemplifies energy transfer by particles. The blast of an air horn demonstrates transfer of energy by mechanical waves, while transmission of light through a vacuum, by suspending a light in a bell jar and evacuating the air, illustrates electromagnetic wave transfer of energy.

Wave Types: Small Group (Three Modules)

Carefully prepared transparencies may be used to show the types of waves. The parts of a wave should be clearly indicated and marked. Each facet of the wave and its motion should be defined and explained. It is important that terminology be clarified before progressing any further. Helical springs (a "slinky" works satisfactorily) show vividly several types of pulses. The wave generator and ripple tank might be used to demonstrate standing waves. Each wave type should be demonstrated by use of an actual model.

Characteristics of Waves: Small Group (Two Modules)

It is recommended that the instructor take the students outside to determine the speed of sound. It can be done quite accurately by firing a gun fitted with blanks and measuring the time lapse between the smoke and the sound over a given distance. All other characteristics should be demonstrated in the laboratory.

Laboratory: Small Group (Four Modules)

Phase, frequency, period, wavelength, and amplitude may all be done or determined experimentally. $f = \frac{1}{T}$; $v = f\lambda$ should be determined by experimentation.

Independent Study

This might include the use of Kundt's apparatus, sonometers, torsion apparatus for studying waves, and resonance apparatus. The instructor can have students perform selected experiments in Scientific Experiments in Physics, or those applicable in Part II of the PSSC Laboratory Guide for Physics. To develop the unit to a greater degree, the instructor may use films and filmstrips such as:

1. Similarity in Wave Behavior
2. Simple Waves

Superposition: Large Group (One Module)

The use of mounted tuning forks, one of which has a slide to adjust the frequency, demonstrates beats which show interference. If adjusted carefully the pulse can be damped out completely. It is also possible to show interference visually by using an oscilloscope.

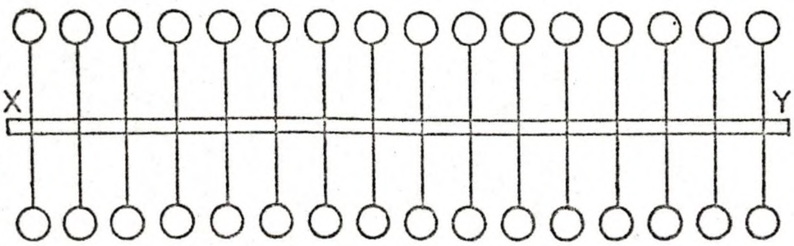
Common Properties of Waves:
Small Groups (Four Modules)

The small group size has been set at twenty in this paper. If enough equipment is available, it is highly recommended that the work pertaining to wave properties be done as a laboratory experiment by pairs of students.

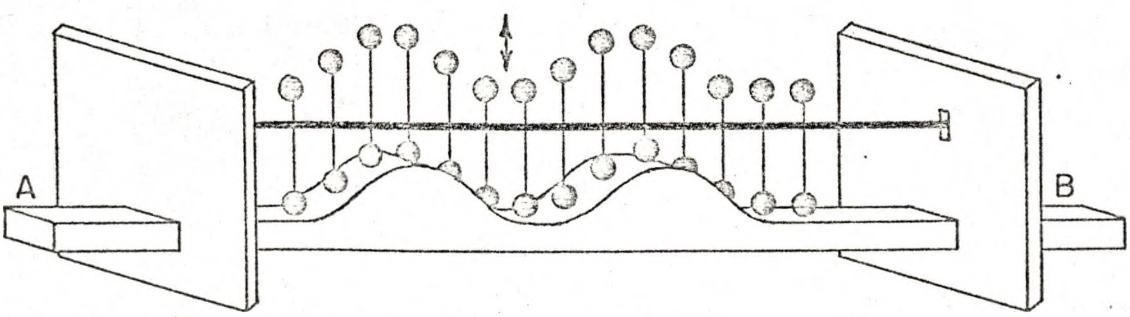
Closure Activities: Small Group (Two Modules)

It is suggested that much of the closure activity be devoted to use of the hand stroboscope to stop and measure the frequency of periodic motion and for observing the behavior of water waves. This should be done as student demonstrations of work done in independent study time.

The following equipment can be student constructed and will serve to reinforce the concepts presented in this unit.



Anchor end X.
Hold end Y
horizontal to X.
Give rod a quick
twist at Y.



Slide bar AB back and forth.
Rods with knobs on the ends
will rise and fall.

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Laboratory Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Lehrman, Robert L. Scientific Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1962.

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Reference Books

Bellamy, D. H. Experimental Physics. Brooklyn, New York: Chemical Publishing Company, 1941.

Pitchford, A. Studies in Geometrical Optics. London: MacDonald, 1959.

Searle, G. F. C. Experimental Optics. Cambridge, England: Cambridge University Press, 1935.

Audio-Visual Aids

Light Waves and Uses. 11 min., B & W.

Similarity in Wave Behavior. 27 min., Bell Telephone Company, Color.

Simple Waves. PSSC 0204, 27 min., B & W.

UNIT VI

SOUND AND AUDIOMETRY

Introductory Note

In a sense, man is rarely creative. He merely uncovers the secrets of the universe. Sound, a phenomena that is so much a part of our modern mileau that its absence would cause consternation, has been studied from the beginning of time. Pure scientists as well as industrial scientists, constantly seek more efficient sound deadeners, producers, and changers. We use sound for communication in radio, telephone, telegraph, and television. Radar and sonar are used to determine location and infrasonic and ultrasonic sounds are used to destroy living things and crush materials. Sound will be studied in relation to its physical properties, not those properties that are basically dependent on the presence of an ear.

Unit Objectives

1. To uncover the general characteristics of sound waves.
2. To discover the basic operations of sound devices.
3. To discuss how sound waves are produced, transmitted, reflected, and absorbed.
4. To gain an understanding of musical sounds and the terminology of sound: pitch, frequency, intensity, beat, and others.

Suggested Outline for Presentation

I. Sound
   A. Origin and production
   B. Transmission by
      1. Solids
      2. Liquids
      3. Gases
      4. Vacuum
   C. Properties
      1. Intensity
      2. Loudness
      3. Pitch
   D. Ranging by speed
      1. Radar
      2. Sonar
   E. Special behavior
      1. Doppler effect
      2. Infrasonic and ultrasonic
   F. Resonance
      1. Tuning forks
      2. Strings
      3. Open and closed pipes
   G. Interference

II. Physical and Sensory Properties of Noise and Music
   A. Diatonic, chromatic and tempered scales
   B. Harmony and discord
   C. Laws of strings

Procedural Activities

Motivational Techniques (Four Modules)

The following films can be shown to introduce the unit and to stimulate student interest.

1.	Sound Waves in Air	35 minutes	(two modules)
2.	Looking at Sounds	10 minutes	)
3.	Music in Motion	18 minutes	) (two modules)
4.	Wire for Sound	10 minutes	)

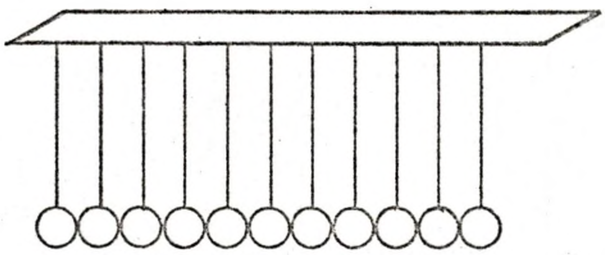
The records, "The Science of Sound," and "Computer Talk," or a modern musical recording of electronic sounds might be used. It is entirely proper to use modern recordings of popular music to set the mood for the study of music.

An oscilloscope allows students to see their voice as a note is sung and compare it with the purer tone of an instrument or a tuning fork.

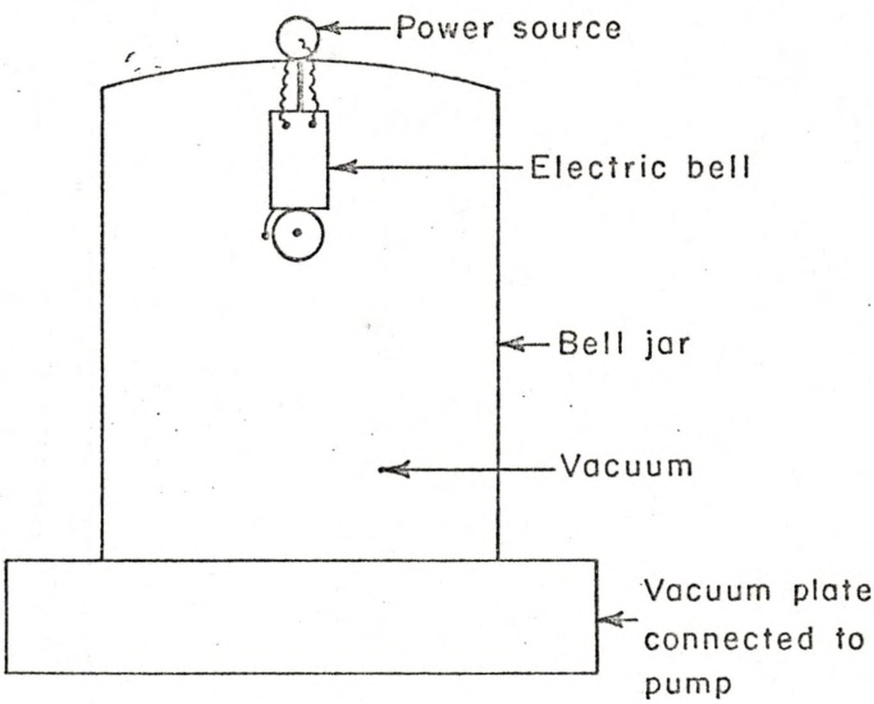
Note: The total time for motivational techniques should be limited to four modules.

Sound: Large Group (Four Modules)

Sounds are produced by matter that vibrates. The quiver of the leaves on a quaking aspen tree or the footsteps of a fly can be heard because matter is caused to vibrate in each case. Sounds can be transmitted only by means of matter in the solid, liquid or gaseous state. The accent should be directed toward an understanding that sound is longitudinal vibration by means of a demonstration model and that it cannot be transmitted in a vacuum. The large group in our physics situation will usually contain no more than forty students, so it is suggested that the following demonstrations be conducted as large group activities.



Ping-pong balls on strings will readily demonstrate longitudinal motion.



By using transparencies, the instructor will explain the relationship of intensity to loudness and frequency to pitch. Then, student demonstrations should be made to reinforce the instructor's presentation.

Independent study reports should be given by students who chose to study radar and/or sonar, Doppler effect, infrasonic, ultrasonic sounds, and other special interest topics.

Suggested Topics: Small Group (One Module)

1. If space is a near vacuum, how is sound transmitted from our man-occupied satellites to earth?
2. Why can a train be heard by placing the ear against a rail before it can be heard through air?
3. What functional parts does the ear have for discerning sound: Demonstrate harmony and discord as an effect on the ear.

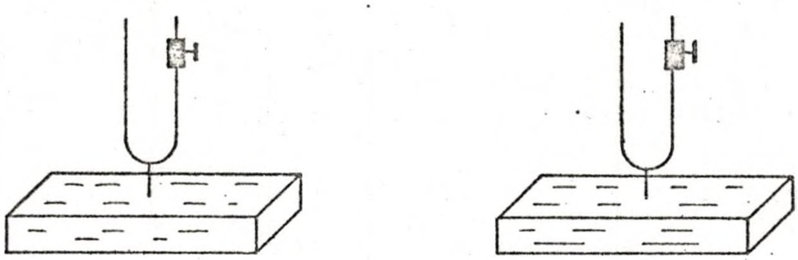
Laboratory (Four Modules)

1. Experiment to demonstrate the laws for open and closed pipes.
2. Experiment to demonstrate the laws of strings.
3. Demonstration by the instructor or students of beats, sympathetic vibration, nodes, and antinodes, using tuning forks and sonometer.

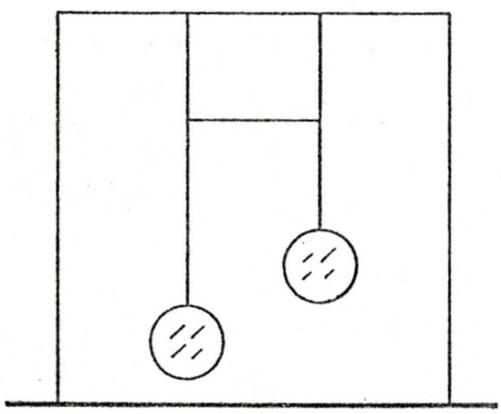
Note: The Doppler apparatus is very effective for demonstrating that principle. "The Science of Sound," a record included in the motivational technique, presents the topic well.

Resonance can be shown by use of the tuning forks as shown in the following diagram, or by use of the pendulum diagrammed below.

adjustable vibration rates



Resonance forks demonstrate beats, reinforcement, and sympathetic vibration.



Pendulums are connected as diagrammed to demonstrate resonance.

Physical and Sensory Properties of Noise and Music

Sounds that are pleasant to the ear are said to be music, while those that are not pleasant are called noise. It should be understood that what is music to one person could well be noise to another. The pitch of a sound is changed by varying the rate of vibration for the sounding apparatus. Quality is determined by the musician and the instrument.

Two violins might produce the same pitch with great divergence in quality, depending upon the construction of the instruments.

Closure Activities

If a violin bow is used to produce the vibration of a sonometer string, nodes and antinodes can readily be marked by the use of riders, strips of paper folded to slip over the string, which jump off at the antinodes and remain on the strings at the nodes.

A tuning fork orchestra is fun for the students.

A stroboscope can be used to view the vibration of strings. It is suggested that some of the better students be utilized to set up demonstrations using more complex equipment such as the oscilloscope.

Bibliography

Textbooks

Castka, Joseph, and Lefler, R. Physics Problems. New York: Holt, Rinehart, and Winston, Inc., 1961.

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Laboratory Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Marburger, Walter George, and Hoffman, C. W. Physics for Our Time. New York: McGraw-Hill, 1955.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

White, Harvey E. Laboratory Exercise for Physics. Princeton, New Jersey: D. Van Nostrand Company, 1960.

UNIT VII

LIGHT AND PHOTOMETRY

Introductory Note

The study of light, a form of energy, takes on a new dimension as transmission is keynoted. It is hoped that as the student studies the wave, corpuscular, electromagnetic, and quantum theories, he will acquire skill in theory formation. The common aspects of motion, illumination, reflection, refraction, and color will be presented for careful consideration.

Unit Objectives

1. To reiterate material pertaining to the transmission of energy by wave motion.
2. To develop the wave and particle models as modes of light transmission (radiation phenomena).
3. To gain an appreciation for the electromagnetic theory through a study of the photoelectric effect.
4. To project the quantum theory (dual nature of light).
5. To understand how the speed, luminous intensity, luminous flux, and other characteristics of light are measured.
6. To familiarize properties such as: rectilinear motion, polarization, finite velocity, refraction, reflection, and others.
7. To provide through demonstration an understanding of images formed by mirrors and lenses.
8. To relate and discuss the operational principles of the microscope, telescope, camera, and other optical equipment.
9. To study color as relevant to light, pigments, and spectrum analysis.
10. To describe polarization of light and its practical application.

Suggested Outline for Presentation

I. The Nature of Light
   A. Huygens': Wave Theory
   B. Newton's: Corpuscular Theory
   C. Maxwell's: Electromagnetic Theory
   D. Planck's: Quantum Theory
   E. Hertz's: Photoelectric Effect
   F. Einstein's: Photoelectric Equation

II. Sources of Light
   A. Luminous bodies
   B. Illuminated bodies

III. Properties of Light
   A. Rectilinear propagation
      1. Rays
      2. Beams
      3. Pencils
      4. Shadows (umbra and penumbra)
   B. Measurable or finite velocity
      1. Velocity in a vacuum (Michelson's experiment)
      2. Velocity in other media (water, air, glass, and others)
   C. Reflection, absorption, and transmission
   D. Photometry
      1. Luminous intensity
      2. Luminous flux
      3. Illumination
      4. Photometers (Bunsen, Joly, and Spherical)
      5. Photoelectric cell
      6. Invisible light
         (a) Infrared
         (b) Ultraviolet

IV. Reflection of Light
   A. Laws of reflection
   B. Regular reflection
   C. Diffused reflection
   D. Mirrors as reflectors
      1. Plane mirrors
      2. Curved mirrors
         (a) Concave mirrors
         (b) Convex mirrors
         (c) Parabolic mirrors

3. Image formation
    (a) Real images
    (b) Virtual images
4. The mirror formula
5. Aberration

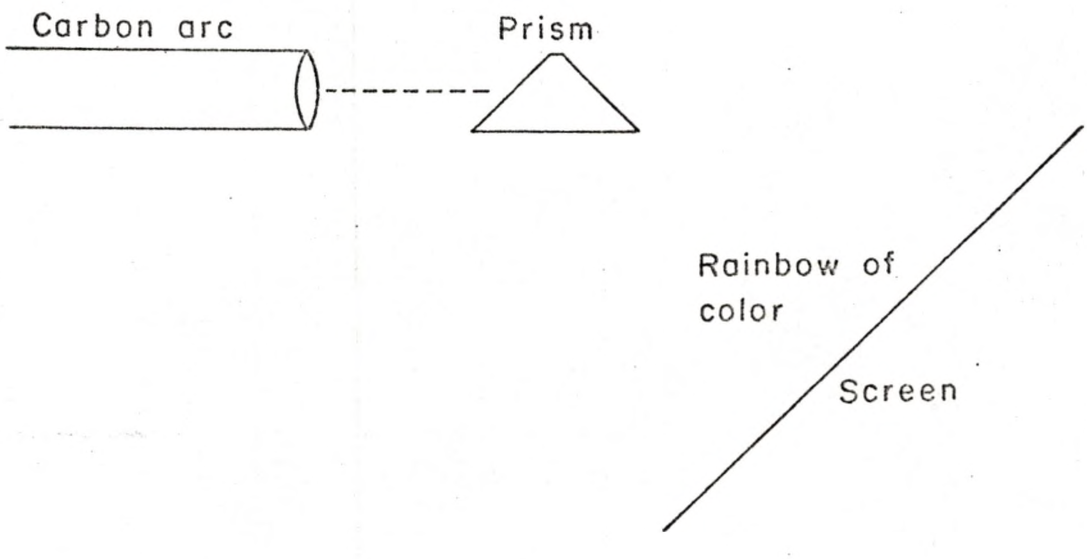
V. Refraction of Light
  A. Optical density, refraction and the speed of light
  B. Index of refraction
  C. Laws of refraction
  D. Atmospheric refraction and mirages
    1. Critical angle
    2. Total reflection
  E. Derivation of Snell's Law
  F. Dispersion and spectra formation
  G. Lenses
    1. Types
      (a) Converging
      (b) Diverging
      (c) Combinations
    2. Image formation
      (a) Real images
      (b) Virtual images
    3. Lens formulas
    4. Aberration

VI. Color
  A. Interference and diffraction
  B. Polarization of light
    1. Methods
    2. Uses

Procedural Activities

Motivational Techniques: Large Group (Two Modules)

Introduce light by showing the PSSC film, Introduction to Optics. Then, in a darkened room students may use diffraction gratings to view a series of spectrum tubes placed on a stand in conjunction with a spectrum tube power supply. The very beautiful array of colored bands and their specific arrangement will enthuse most students. It is also suggested that a prism and a light source be set up to produce a rainbow on a screen. If a Kirchoff and Bunsen spectroscope is available, the students can look at a sodium or mercury vapor light source through it. The color change of fluorescent minerals, liquids and powders when exposed to ultraviolet light can also be used to motivate. This large group period should be used for observation and not for discussion of what is being viewed.



<u>The Nature of Light: Large Group (Three Modules)</u>

There are several things that come to mind when the study of light is undertaken. Two of the early questions would likely be: (1) Where does light come from or originate, and (2) How does it get from one place to another?

Consider the sun as a source of light. Explain the transmission of light to the earth, by adhering to the wave theory. This will enable the students to discover the strengths and shortcomings of the theory. Proceed to study in a similar manner the corpuscular, electromagnetic, and quantum theories. Endeavor to discover the strengths and weaknesses of each theory as an explanation of light transmission.

<u>Sources of Light: Small Group (One Module)</u>

Objective: To demonstrate the transition of rays from the invisible to the visible.

Materials: Any incandescent light source, a rheostat, and an ammeter. A sensitive photometer is desirable also.

Procedure: Connect the light source, rheostat and ammeter so that an increased current, as indicated by the ammeter and regulated by the rheostat, can cause the light to fade or to brighten. Regulate the rheostat to demonstrate this change.

Conclusions: When the current is increased, it produces a corresponding increase in the light source brightness.

Demonstrate the difference between luminous and illuminated bodies.

Properties of Light: Large Group (Three Modules)

Pass a beam of light from a carbon arc through a small hole. This allows the student to observe the rectilinear property of light transmission. If chalk dust is placed on the beam's path, the straight line characteristics of the beam are emphasized. The dust causes some of the light to scatter or diffuse as particles of chalk are struck by the beam. Carefully explain the relationship of the terms ray, beam, and pencil of light.

Using a light source and an opaque object, cast a shadow upon a screen. Indicate the regions referred to as the umbra and penumbra. Discuss shadow formation as related to light traveling in a straight line. Briefly compare light and sound in relation to ability to bend around corners.

The speed of light is an important constant in physics. The students who have been doing independent study on Roemer and Michelson should be asked to report to the entire group. The methods for determining the speed of light employed by the two men were very different. The instructor should suggest the use of visual aids such as:

an overhead projector and transparencies, pictures and an opaque projector, and models constructed by the student if possible. The reports should be written so that copies could be given to each student for future reference and discussion in the small groups. Independent study projects, papers, and reports should whenever possible cross over course lines.

After the small groups have discussed the concept of speed of light, the PSSC film, Speed of Light, should be shown.

Note: Light has been observed to exert pressure. This can best be illustrated and explained by showing the PSSC film, Pressure of Light. All films should be shown as large group activities. The radiometer should not be used to explain light pressure, because it exemplifies a fallacy in man's thinking. It operates on the push exerted by expanding air as the air becomes heated more on the dark side of the vane. The darkened area absorbs light at a faster rate, and when the light energy changes to heat energy it is warmed more than the light side of the vane. The discussion on the radiometer should be done before the large group, but the radiometer should be taken to the small group for observation. A brief explanation of the velocity of light in media other than air and in a vacuum should be made in conjunction with the explanation.

As the study of photometry is initiated, care should be exercised to define thoroughly all terms. For example, it is imperative that the student understand clearly the "candle" unit.

Photometry: Large Group (Four Modules)

The common unit of intensity is the candle. It is defined as the intensity of the light emitted through an opening 1/60 of a square centimeter in area from a hollow enclosure maintained at the temperature of solidification of platinum, about 1773° C. This can be demonstrated with sophisticated equipment not found in an ordinary school laboratory. In the formula below, the symbol I is used for intensity.

Luminous flux and the lumen should be related and the formula clearly explained. $F = \frac{4\pi \text{ lumens} \times I}{\text{candle}}$ (candles)

Illumination is the density of the luminous flux on a surface. This statement brings the student in contact with the following formulas:

1. $E = \frac{F}{A}$

2. $E = \frac{F}{A} = \frac{4\pi I}{4\pi s^2} = \frac{I}{s^2}$

E = illumination

F = luminous flux $= 4\pi I$

A = area of the surface $= 4\pi s^2$

The illumination on a surface varies directly with the cosine of the angle between the luminous flux and the normal to the surface. Then,

$$E = \frac{I \cos \theta}{s^2}$$

Laboratory (Two Modules)

Do an experiment using the optical bench and a Bunsen photometer to reinforce the inverse square law:

1. Experiment number 35, Laboratory Experiments in Physics, or

2. Experiment number 42, Scientific Experiments in Physics.

Proficiency in problem solving should be achieved during small group instruction.

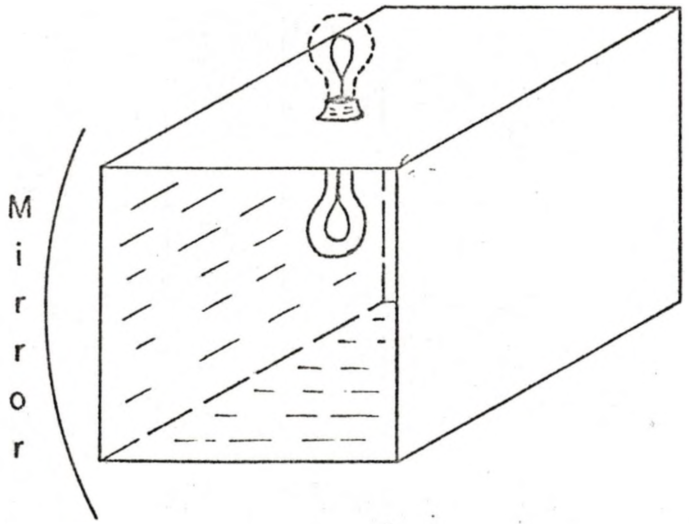
Reflection of Light: Small Group (Two Modules)

Each small group should have large convex, concave, and plane mirrors. The curved mirrors should be at least twenty-five centimeters in diameter. The groups will need a light source, objects, screens, and an optical bench on which all equipment may be mounted. After the small groups have discussed the terminology that is applicable to reflection of light, all equipment should be transported to the laboratory.

Laboratory (Four Modules)

Do an experiment that will reinforce the laws of reflection. Set up the cases for curved mirrors.

Analogies can be drawn by using a "high bounce" ball and throwing it on the floor at various angles of incidence to observe the angle of reflection. If the spin of the ball could be discounted, the angles would be nearly equal, even though the ball is not perfectly elastic. The ripple tank may be used very effectively to demonstrate the reflection of waves, and if a hand stroboscope is used the motion can be observed more closely. Caution: Do not confuse the angle and its complement. In a darkened room a large plate glass mirror could be placed on the instructor's desk top and a beam of light directed on it at an angle. The angle of incidence and the angle of reflection can be explained with added understanding by measuring the angles. The following apparatus makes a rather spectacular demonstration.



The actual light bulb is within the black box. However, when focused properly the image of the bulb appears in the empty socket on the box top.

The light bulb, which is in the box, appears to be in the empty socket on the top of the box. The PSSC Teachers Resource Book describes a projection of a bouquet of flowers in space by means of spherical mirrors or parabolic mirrors. These experiments are recommended highly to increase student interest. They may be set up by students doing independent study.

Laboratory

There are many experiments that can be done in connection with mirrors. The instructor must make his own selection.

1. Experiment number 43, Scientific Experiments in Physics.

2. Experiment number 47, Laboratory Experiments in Physics.

3. Experiment number II-2, PSSC Laboratory Guide for Physics.

Note: There are several films listed at the end of this unit that pertain directly to the study of reflection.

Refraction of Light: Small Group (Two Modules)

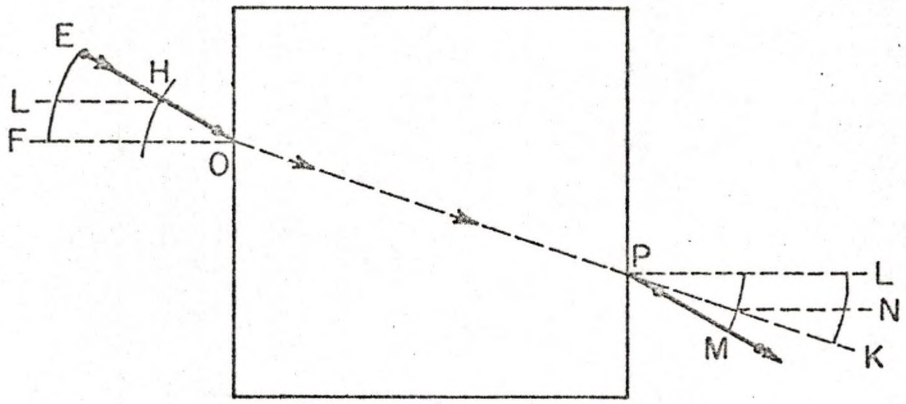
Light bends or refracts as it travels from one media to another of a different optical density. This section is concerned with the behavior of light during refraction. As an introduction to refraction, conduct the following demonstration:

Objective: To acquaint the student with the phenomena of light refraction.

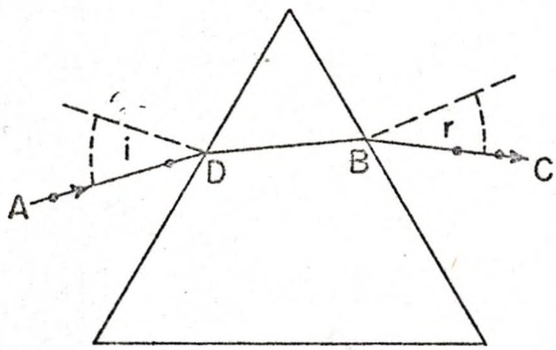
Materials: Cardboard, pins, a glass plate with parallel sides, an equilateral triangular glass, and a right angle glass triangle. The three high grade glass objects are approximately one centimeter in thickness.

Procedures: Set up the apparatus as shown on the following page. Arrange two pins on viewer's side of the plates and look along a line made by them through the plates. Place two more pins on the opposite

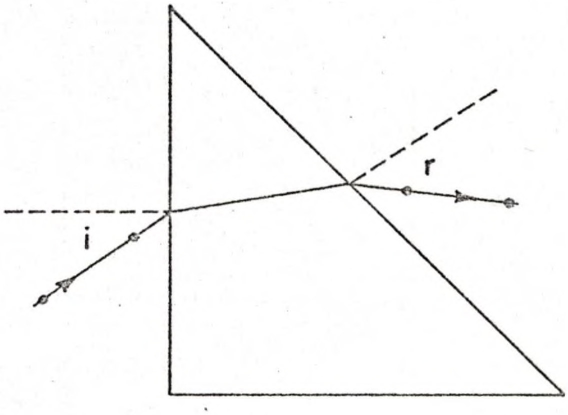
Glass Plate with Parallel Sides



Equilateral Triangle



Right Triangle



side of the plates so that they seem to form a straight line with the first pins. Remove the plates and draw in lines as indicated by the pins.

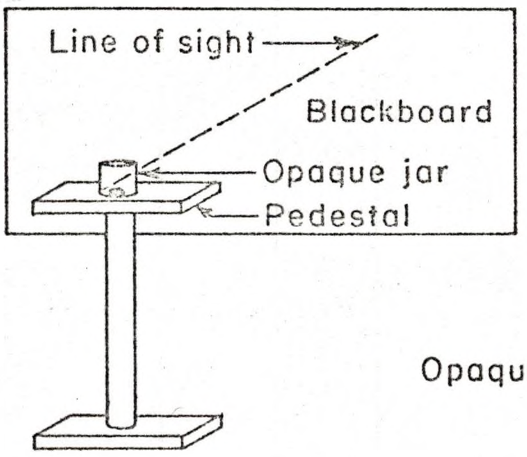
Conclusions: Light is refracted as it enters and leaves the plates.

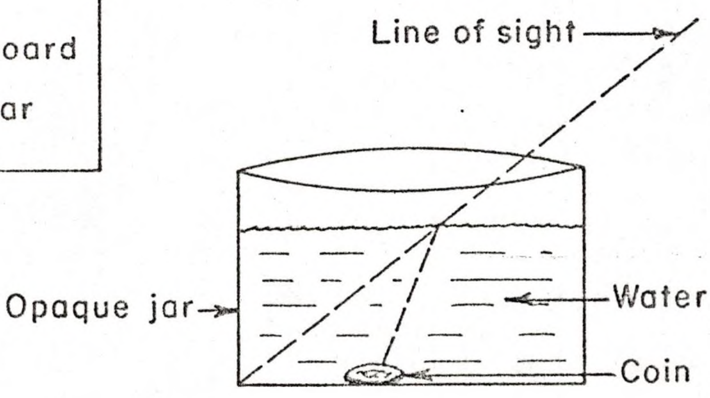
If another example of bending light rays is desirable, it is easy to perform the following demonstration. The demonstration is most effective if the containing vessel is opaque. Do not use a beaker.

Small Group (One Module)

Place the containing vessel on a pedestal against the blackboard. Draw the line of sight for the eye on the board. Attach the coin to the bottom of the container so that it cannot move when the water is added. What happens if a different liquid is used?

If the eye follows the same line of sight as it did before the water was added, the coin will come into view. The fixed position of the coin should be noted so that the line segment can be drawn to indicate the bending of the light.

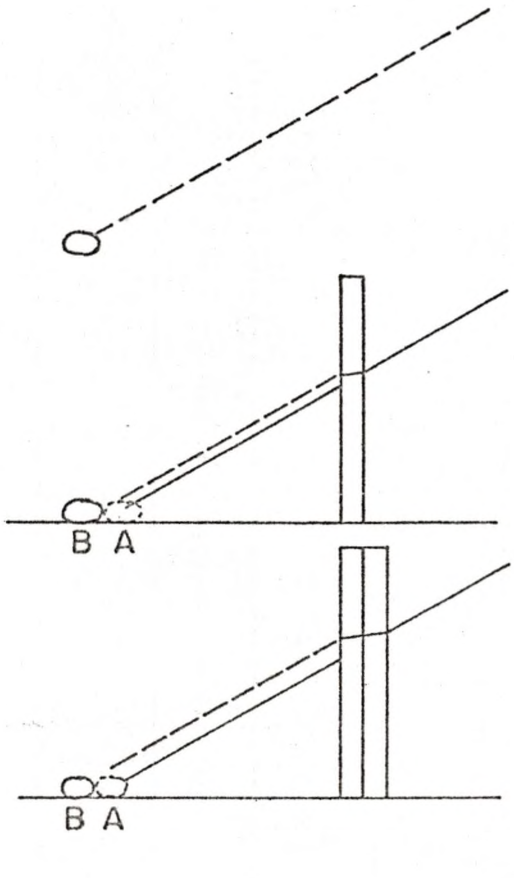




Try the same experiment using clear glycerin, liquid gelatin, hypo solution, and others. Exercise care in the measurements that are taken so that a difference can be noted even though it might be slight.

Perhaps one of the most effective demonstrations of refraction is the following:

Place a coin on the desk top. Slide a single plane-sided glass plate in front of the coin. Note how the coin seems to move as the plate is caused to slide back and forth. Repeat, using two glass plates to give added thickness.



The coin seems to be at point A, but it is actually at point B.

Discussion Question

If you were standing by a lake and wanted to spear a fish swimming off-shore, where would you throw the spear?

It might be of interest to the class to discuss the phenomenal accuracy of the archer fish as it captures food.

Prisms should be available for individual student use during their independent study time so that more sophisticated experiments may be conducted.

Index of Refraction: Large Group (Two Modules)

Light does not travel in all media at the same speed. In a vacuum, it travels approximately 186,000 miles per second. In water the speed is reduced to about 140,000 miles per second and if ordinary glass becomes the media for transmission, we note a further reduction of speed to about 124,000 miles per second.

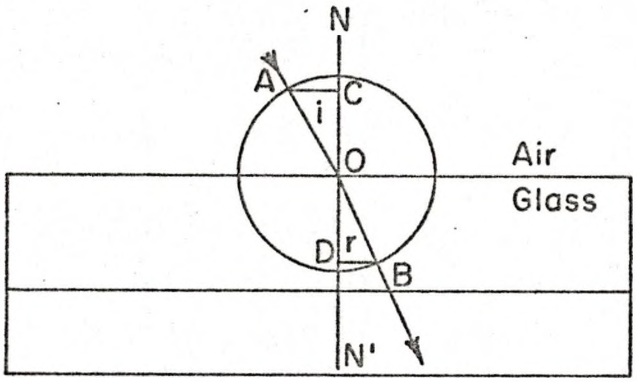
When we consider the speed of light in a vacuum as a ratio to the speed of light in a substance, the index of refraction is determined. The index of refraction equals $\frac{\text{speed of light in a vacuum}}{\text{speed of light in a media}}$. Accordingly, the index of refraction for ordinary glass would be determined as follows:

$$n = \frac{186,000}{124,000} = \frac{3}{2} = 1.5$$

If the index of refraction were desired for water, it would be found by dividing 186,000/140,000.

It is interesting to note that Willebrord Snell (1591-1626) discovered the fundamental principle of refraction to be the ratio of the sine of the angle of incidence to the sine of the angle of refraction. The geometric construction of Snell's Law and its explanation follow:

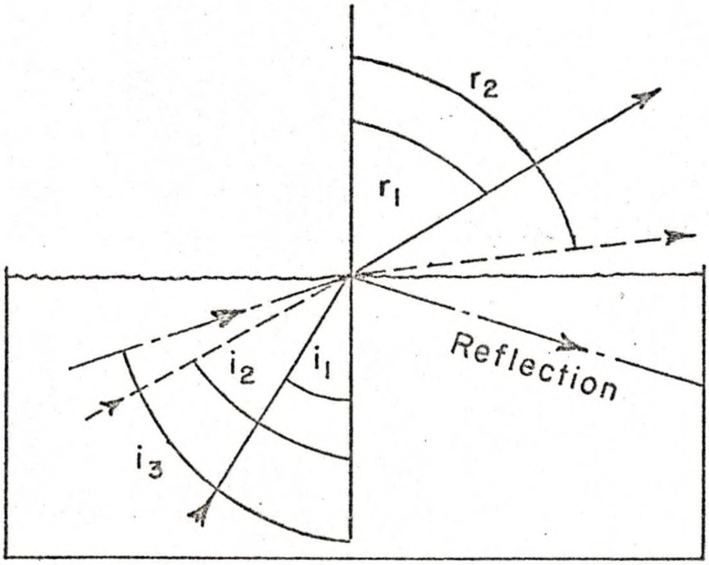
$$n = \frac{\sin i}{\sin r} = \frac{AC}{DB}$$



The line AO represents a ray of light through the air, incident upon a glass plate at point O. This ray is refracted as it enters the glass along the path OB. To find the index of refraction, a circle is drawn in the plane of the ray about point O and the normal to the surface of the glass at point O is drawn as NN'. The lines AC and DB are drawn perpendicular to NN'. Since AO and OB are radii of the same circle, they are equal.

Schematic Demonstration: Large Group

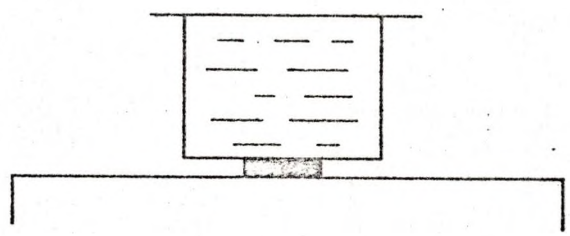
The question may arise as to what happens when the light source is placed within the more dense media and the rays of light travel from that media into the air. What path will the light take? Does it reverse itself? With a brief explanation, students should understand that reversal occurs. Well-prepared transparencies using color aid in clarification. It should also be shown schematically that as the angle of incidence for a beam or ray of light which is traveling from a more dense media to a less dense media increases the angle of refraction becomes greater. When the refraction angle is 90°, the light ray will be reflected totally. If the angle of refraction is greater than 90°, all light will be returned to the more dense media.



During the experiment i_1 produces r_1, and i_2 goes along path r_2. This is refraction. However, when i_3 is great, reflection occurs.

Actual Demonstration: Small Group

When a clear water glass or beaker is placed on top of a coin, the coin is clearly visible through the sides of the glass as well as from the top. If the top is covered and the glass filled, the coin disappears.



Dispersion and Spectra Formation

Each student should be supplied with a prism and a diffraction grating. He should observe the continuous spectrum emitted by sunlight, incandescent sources, and some reflective matter. The grating may be used to observe the bright and dark lines emitted by spectrum tubes, and sodium and mercury arc lamps. If a spectroscope is available, the student should have an opportunity to observe the arc lights through it.

Laboratory: Experiment with
Spectrum Analysis (Two Modules)

Objective: To observe the band absorption spectrum produced by chlorophyl in solution.

Materials: Fleshy green leaves, ethyl alcohol, 250 ml. beaker, test tube, water, hot plate, and a light source.

Procedure: Soften the leaf tissue by boiling the leaves in a beaker containing water. After a few minutes, the leaves should be taken from the water and placed in a beaker containing ethyl alcohol. Gently boil the ethyl alcohol and leaves until an appreciable amount of chlorophyl enters the alcohol. Pour the chlorophyl solution into a test tube. The solution should be placed in a strong beam of light and viewed through a spectroscope.

Observations: (1) The beam of light without the chlorophyl solution emits a bright continuous spectrum. (2) Conspicuous dark bands are seen when the chlorophyl solution is placed in the beam and observed through the spectroscope.

Conclusions: (1) Chlorophyl produces a characteristic band spectrum. (2) Chlorophyl can be identified by spectrum analysis.

Note: Standard spectra charts should be available for comparison.

Laboratory: Experiment with Converging and Diverging Lenses Setting Up All Cases (Four Modules)

Small groups should then determine the lens formulas, $\frac{h_o}{h_i} = \frac{s_o}{s_i}$ and $\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$.

The discussion and problem solving will take at least two modules.

Laboratory: Experiment II-4 in the PSSC Laboratory Guide for Physics, or Experiment Number 45 in Experiments in Physics (Two Modules)

These two experiments may be completed.

Summary Discussion: Large Group

1. Aberration

2. Structure and defects of the human eye

3. Simple magnifiers, microscopes, telescopes, and the formulas pertaining to their operation.

Color: Large Group (Two Modules)

In a well-darkened room, the instructor should provide each student with a diffraction grating and complete the demonstration of the spectrum tube series used to introduce the light unit. It is hoped that a Singerman Color Mixer is available for this study of color. With the built-in screen readily visible on the color mixer the instructor will mix the various light colors and produce the experiences desired. The color mixer will:

1. Produce each spectral color.

2. Demonstrate the primary colors.

3. Show the combination of complementary colors.

If an infrared photography apparatus is available, a picture of the class should be taken while the room is thoroughly darkened and projected by means of an opaque projector. With the lights on, the group should see a rotating color disc with the primary pigment colors. The instructor should show the characteristic differences between primary light colors and primary pigment colors.

Discussion of the Rainbow:
Small Group (One Module)

A good introductory point of interest is a discussion of the rainbow as presented in PSSC Teacher's Resource Book and Guide, Appendix 2, Supplement to Chapter 13. Topics for discussion might include: Why is the rainbow "bow" shaped? What causes the color of a rainbow? How are the colors arranged in a rainbow, and why? How is a double rainbow formed? Explain the inversion.

Development of a Light Model:
Large Group (Two Modules)

The unit on light was begun with a discussion of the four most common theories pertaining to light transmission. Each theory should be reviewed with the students and weighed as to its merits. Strive for student formulation of a satisfactory model. When the models have been discussed, introduce diffraction and interference. Does the light model developed by the students still answer the behavior problems to a satisfactory degree?

Laboratory: An Experiment on
Interference (Four Modules)

Student "team-learning" pairs should work with ripple tanks setting up constructive and destructive interference patterns, as well as phase relationships of sources. Help the students discover the analogy between light and water wave behavior.

Young's experiment which produces a visible interference pattern on a screen should be done.

Experiment II-14 from PSSC Laboratory Guide for Physics and/or experiment number 47 from Scientific Experiments in Physics are selected for this purpose.

Laboratory: An Experiment on
Diffraction (Two Modules)

Experiment II-15 from PSSC Laboratory Guide for Physics is suggested.

Discussion: Small Group (One Module)

The optical geometry of a transmission grating for determining wavelength by diffraction should be discussed.

$$\lambda = \frac{d \sin \theta_n}{n}$$

Polarization: Small Group (Two Modules)

Discussion questions such as: (1) What is polarized light? (2) What are a polarizer and an analyzer? (3) Examine and then explain how polaroid disks function. (4) What is plane-polarized light? The instructor should use a tourmaline crystal to show polarization by selective absorption. Use glass plates and polaroid disks to show polarization by reflection. A clear crystal of calcite may be used to illustrate polarization by double refraction.

Discussion of Uses of Polarized Light: Small Group (One Module)

Laboratory: Experiment Number 56 from Laboratory Experiments in Physics

This experiment is suggested.

Closure Activities

Demonstration

A demonstration of the use of polarized light to determine structural strain can be made by placing a small section of transparent plastic between two polaroid disks located on an overhead projector. When the plastic is twisted, the projected color pattern will display the areas of maximum and minimum strain.

1. Testing: two parts (two modules per part)

2. Films: Refer to bibliography (four modules).

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

White, Harvey E. Laboratory Exercise for Physics. Princeton, New Jersey: D. Van Nostrand Company, 1960.

White, Harvey E. Modern College Physics. 4th ed. Princeton, New Jersey: D. Van Nostrand Company, 1962.

Reference Books

Brinckerhoff, R. F.; Cross, J. B.; and Lazarus, A. Exploring Physics. New York: Harcourt, Brace and World, 1959.

Castka, Joseph, and Lefler, R. Physics Problems. New York: Holt, Rinehart, and Winston, Inc., 1961.

Marburger, Walter George, and Hoffman, C. W. Physics for Our Time. New York: McGraw-Hill, 1955.

Pitchford, A. Studies in Geometrical Optics. London: MacDonald, 1959.

Verweibe, Frank L.; Van Hoof, Gordon; and Suchy, Robert R. Physics, A Basic Science. Princeton, New Jersey: D. Van Nostrand, 1962.

Periodicals

Ahlgren, Andrew. "Experiments with Simple Equipment--A Light Projector for Refraction Experiment." The Physics Teacher, May, 1963.

Bond, Burtis B. "A Ripple Tank Stroboscope." The Science Teacher, Vol. XXX, No. 5.

Burch, J. M., and Macfarlane, G. G. "The Optical Maser--A New King of Light Source." The Times Science Review, Quarterly No. 42, Winter, 1961.

Chapman, Seville, and Meese, D. "Interference of Light." American Journal of Physics, March, 1957.

Clark, Mary Lou. "Measuring the Wavelength of Light." The Physics Teacher, February, 1964.

Kleppner, Daniel. "Stimulated Emission and the Maser." The Science Teacher, February, 1964.

Land, Edwin H. "Color Vision." Scientific American, May, 1959.

Long, Robert H. "An Apparatus Introducing the Principle of Polarized Light." The Science Teacher, September, 1956.

Schawlow, Arthur L. "Optical Masers." Scientific American, June, 1961.

Sprecher, Roland O. "A Demonstration Lens." The Science Teacher, December, 1958.

Tomer, Darrell. "Strophotography." The Science Teacher, May, 1960.

Audio-Visual Aids

Electromagnetic Waves. 30 min., B & W.

Eye to the Unknown. 35 min., Color (free loan), Modern Talking Service, 3 E. 44 M Street, New York, New York.

Interference of Photons. PSSC 0419, 16 min., B & W.

Introduction to Optics. PSSC 0201, 23 min., B & W.

Light and Illumination. 11 min., Color.

Light Waves and Uses. 11 min., B & W.

NAA Optical Laboratory. 10 min., Color (free loan), North American Aviation, Inc., International Airport, Los Angeles, California.

Nature of Color. 11 min., Color (rental), Coronet Films Company, 6 E. South Water Street, Chicago, Illinois.

Photons. PSSC 0418, 25 min., B & W.

Polarized Light. (Rental), #617 F.O.M., McGraw-Hill, 41 frames, Color.

Pressure of Light. PSSC 0202, 23 min., B & W.

Principles of the Optical Maser. 30 min., Color (free loan), Bell Telephone Company.

Science of Color Photography. (Rental), #576 F.O.M., McGraw-Hill, 42 frames, Color.

Speed of Light. PSSC 0203, 21 min., B & W.

The Story of Lenses. #579 F.O.M., McGraw-Hill, 42 frames, Color.

UNIT VIII

ELECTRICITY: STATIC AND CURRENT

Introductory Note

The physics student is to be made aware of the concepts, rules and laws, that are involved. He is not to become a circuitry builder or designer except as his interest might direct him during independent study. He should understand the indestructibility of electric charge, and that such charge can be transferred and utilized. The effects of an electric field on particles near and within that field become pertinent points.

Unit Objectives

1. To develop an understanding that matter has an electrical structure.
2. To direct students toward an understanding that concepts of charge and electric field are necessary.
3. To relate how men of science work with the unknown, use it and gradually come to an understanding of its values.

Suggested Outline for Presentation

I. Electrostatics
   A. Electric charges
      1. Positive charge: glass rod and silk will produce (+) on rod
      2. Negative charge: plastic rod and fur will produce (-) on rod
   B. Demonstration of forces exerted by charged particles and bodies
      1. Two electrified glass rods repel each other
      2. Two electrified plastic rods repel each other
      3. A charged glass rod attracts a charged plastic rod
      4. The pith ball or leaf electroscope may be used to detect an electrostatic charge, and to show that like charges repel while unlike charges attract
         (a) Charging by induction and induced charges
         (b) Charging by conduction and unbalanced potential
   C. Coulomb's law of electrostatics
      1. The force between two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distances between them
      2. $F = k \frac{Q_1 Q_2}{s^2}$

         $k = 9 \times 10^9$ nt $m^2/coul^2$
         Q_1 = coulombs
         Q_2 = coulombs
         s = meters
         F = newtons of force
   D. Atoms as particles having a charge or not having a charge
      1. If a body is neutral, the resultant force exerted by all the electric particles on any particle is zero
      2. A body can be neutral on the average and, nevertheless, contain areas of concentrated electric charge
   E. Fields of electric force and electric potential
   F. Capacitance and dielectric constant

II. Electric Current
   A. Difference of potential
   B. Electromotive force
   C. Electric current
      1. Conductivity of gases and ionization
         (a) Cloud chamber
         (b) Discharging effect of x-rays

2. Conductivity of solutions
3. Conductivity of solids

D. Insulators and conductors

E. Sources of electromotive force: voltaic cell and the volt

F. Ohm's Law of Resistance

1. $R = \frac{E}{I} = \frac{\text{volt}}{\text{ampere}} = \frac{\text{joule/coulomb}}{\text{coulomb/second}}$
2. $R = \frac{\text{joule second}}{\text{coul}^2} = \frac{\text{kg m}^2\text{/sec}}{\text{coul}^2}$
3. Resistance in series
4. Resistance in parallel

G. Resistivity--dependence on:

1. Temperature
2. Length of conductor
3. Cross-sectional area
4. Nature of the material

H. Measurement of resistance

1. Voltmeter-ammeter method
2. Wheatstone bridge method

III. Electrical Units and Electric Power

A. Ampere

B. Volt

C. Ohm

D. Coulomb

E. Electric power

1. W = VIt
2. Joule's law; W = JQ; power = energy/time

IV. Electrolysis

A. Electrolytic cell

B. Electroplating

C. Faraday's laws of electrolysis

V. Electromagnetism and Magnets

A. Magnets and magnetic fields

1. Domain theory of magnetism
2. Flux density, field intensity, permeability, unit pole

B. Electromagnets

1. Oersted experiment
2. Ampere's rule for a straight conductor
3. Ampere's rule for a solenoid

VI. Alternating Current Circuits
   A. Impedance
   B. Capacitance
   C. Resonance

Procedural Activities

Motivational Techniques: Large Group (Two Modules)

In a well darkened room, the Van De Graff generator with an insulated sphere may be used to produce sparks twenty-five to thirty centimeters in length. In this manner, a tube-type fluorescent lamp may be lighted, and the light can be wiped from the tube by running the hand along the tube. The accessory set for the Van De Graff makes an excellent stimulator of interest. The Wimshurst static machine with the accessory set should be demonstrated also.

Laboratory: Small Group (Four Modules)

Objectives: (1) To understand the basic concepts pertaining to static electricity. (2) To develop concepts relative to the understanding of magnets and magnetism.

Materials: Magnetizer, magnets, alnico bar and disk magnets, magnet model (Welch No. 1800), glass tank, iron filings, soft iron rods, corks, and non-magnetized sewing needles. Electroscopes, glass rods, plastic rods, fur, electrophorus, hollow cylinder, induction cylinder and an ellipsoidal conductor.

Procedures: Selection becomes difficult when there are many experiments that may be done.

1. Demonstrate the difference between plus and minus charges.

2. Demonstrate charge transfer, charging by induction, residence on outer surface of a conductor, dependency on the curvature of the surface.

3. Demonstrate attraction and repulsion of magnets.

4. Demonstrate the formation of a magnetic field and illustrate the theory of molecular magnets.

5. Float needles with corks in a glass tank containing water and observe their behavior when strong, alnico magnets are brought into the field.

Observations: List what is seen by the students. The small groups should discuss the cause and effect relationships.

Conclusions: (1) There are two kinds of fields, the magnetic field around a magnetized object and the electric field around an electrified object. Conductors and non-conductors behave differently in the two fields. (2) The field force is exerted through a distance so it need not be a contact force.

The experiments in Part IV of the PSSC Laboratory Guide for Physics are recommended highly. The PSSC Teacher's Guide for Laboratory Experiments has several demonstrations that are excellent. In a large group instruction session of two modules, the best of the experiments may be selected for teacher presentation or by students who have chosen to become well-versed in this particular area as an independent study project.

Large Group (One Module)

1. Explain the theory of electrostatics.

2. Explain the theory of magnetism.

Electrostatics: Small Group (Two Modules)

Thumbnail sketches of Thales, Gilbert, Franklin, Davy, Faraday, Perrin, Crookes, Thompson, Becquerel, Millikan, Bohr, and Chadwick may be presented to the class as student reports. Each report is of necessity brief and designed to stress only the contribution to physics. Stress the birth and development of ideas. Discuss the meaning of discovery, rediscovery, and hypothesis.

Laboratory: Small Group (Two Modules)

Objectives: To demonstrate the discharging effect of a Tesla high frequency coil on electroscopes that have been given a charge, and to show the attraction and repulsion of charged bodies.

Materials: Tesla coil, electroscopes, Geissler tubes, weak magnets, and cotton.

Procedures: Charge an electroscope by conduction and place it on one end of the instructor's laboratory desk. Turn on the Tesla coil at the other end of the desk and watch the electroscope react to the electrification of air molecules through the gap separating it from the coil. Hold the operating coil near Geissler tubes and observe the effect produced.

Touch the Tesla coil spark to a weak magnet. Let the spark touch cotton soaked in alcohol.

Observations: The electroscope is discharged more rapidly when the coil is operating. The Geissler tubes glow. The magnet is weaker than before. The cotton ignites.

Conclusions: (1) The electroscope discharges because the Tesla coil ionizes the air molecules and permits charge loss through conduction. The odor of ozone can be detected. (2) Geissler tubes are discharge tubes and glow in the presence of a high-frequency discharge. (3) High-frequency discharge causes magnets to lose their magnetic strength. (4) The ignited cotton indicates that the Tesla coil produces a high-frequency discharge that has a heating effect also.

It is of interest and value for students to plot fields and to use an electric field mapping set designed to show various configurations (Welch No. 1960). If a small stream of water is approached by a charged rod, it will be attracted to the rod. The rod is discharged if allowed to touch the stream. This attraction is very similar to the pith ball and rod reaction.

Films: Large Group (Two Modules)

1. Electrostatics, 11 minutes, Resource Center
2. Magnetism, 15 minutes, Resource Center

3. Electrochemistry, 11 minutes, Resource Center

4. Coulomb's Law, 30 minutes, PSSC

Filmstrips: Large Group (One Module)

1. Electricity and Magnetism, Resource Center (set of three)

2. Electricity, Resource Center (set of two)

Difference in Potential and Current Electricity: Small Group (Eight Modules)

The ampere, which is one coulomb per second, is the most widely used unit of current. The definition of the international ampere is based on the rate at which silver is deposited by an electric current passing through a solution of silver nitrate. In the MKS system, the ampere is defined in terms of force between two parallel conductors. The coulomb is defined as the quantity of electricity equal to the charge on 6.25×10^{8} electrons. One electron, a single unit of negative electricity, carries a charge which is equivalent to 1.6×10^{-19} coulomb. If 6.25×10^{18} elementary charges (electrons) move past a point in one second, we have an ampere or a coulomb per second. The copper or silver voltmeters (coulombmeter) may be used to measure accurately a quantity of electricity passing through it. The potential difference between two points in an electric field such that one joule of work moves a charge of one coulomb between these points is a volt. The volt is the MKS unit of potential difference or electromotive force or emf. The volt

; equal to one joule/one coulomb or 1.6×10^{-19} joules per elementary harge. The electron volt is commonly used as a measure of electrical nergy. It is equivalent to 1.6×10^{-19} joules. Terminology should be clearly set forth at the beginning of this unit.

Laboratory: Small Group

1. An experiment may be conducted to prove Ohm's Law of Resistance. It should deal with both series and parallel circuits.
2. An experiment should be done that relates temperature, length, cross-sectional area, and nature of the material to the laws of resistance.

Electrical Units and Electric Power:
Large Group (Two Modules)

The teacher should stress that concepts are the aims of this study. The relationship of laws is the important factor in the learning process not the memorization of isolated facts. The instructor may add a practical aspect when electricity is studied. It should be related to day by day use in the home. Start with the unit of force, the newton, and continue until all work and power units have been shown to be interrelated. Discuss, also, Joule's Law.

Electrolysis: Small Group (Two Modules)

Pure water is essentially a non-conductor of an electric current. Why, then, is it so dangerous to work with electricity when the conditions present a wet environment? The conductivity of water may be demonstrated by the use of an electrolytic cell. There is a negligible amount of action until a few drops of an acid, for example, are added to the water. The presence of the acid allows ion movement during the electrolysis of the water. It is found that the passage of 96,500 coulombs through the solution releases one gram-atomic-weight of hydrogen, which is monovalent, and only one-half gram-atomic-weight of oxygen, a divalent element. Faraday's laws of electrolysis have meaning with this experiment. A student working an independent unit on electroplating should demonstrate his project to each small group. Experiment IV-6, "The Charge Carried by Ions in Solution," from the PSSC Laboratory Guide for Physics is recommended. A brief study of the construction and care of the storage battery will be of some interest.

Electromagnetism and Magnets:
Small Group (Two Modules)

An electromagnetism demonstration set (Welch No. 2462) shows many fundamental effects of magnetic fields while using A.C. and D.C. This is recommended as a teacher or student demonstration to be done for small groups, because students must be close to see some of the effects. There are several films dealing with ferromagnetic domains that may be obtained from Bell Telephone.

1. Part I: Magnetism and Domains, 11 minutes

2. Part II: How They are Formed, 11 minutes

3. Domains and Hysteresis in Ferromagnetic Materials, 36 minutes

Bell Telephone also have a filmstrip-recording combination entitled "The Formation of Ferromagnetic Domains," which is forty-five minutes in length. It is not recommended that all the aids mentioned be used. The instructor should select the films and filmstrips to be shown.

Special Reports by Individuals from Independent Study and Film: Large Group Activity (Three Modules)

The reports on Clerk Maxwell, James Franck, Gustav Hertz, J. J. Thomson, Niels Bohr, and Ernest Rutherford will illuminate the study of electromagnetism. The PSSC film, Franck-Hertz Experiment, twenty-five minutes, should be viewed.

Laboratory: Small Group (Two Modules)

Experiment IV-9, "The Measurement of a Magnetic Field in Fundamental Units," from PSSC Laboratory Guide for Physics is recommended.

Closure Activities: Small Groups (Four Modules)

During independent study a student may have studied capacitance and inductance. If so, he should be asked to display the Choke and

Resonance demonstration to small and large groups.

Another suggested demonstration employs the use of primary-secondary coil set to demonstrate electromagnetic induction effects.

Cathode-ray tubes that depict the following effects should be demonstrated in a darkened room:

1. Heating effect
2. Deflection effect
3. Shadow effect
4. Kinetic-energy effect
5. Fluorescent effect
6. Focusing effect
7. Directional effect
8. Canal rays

As an independent study project a cathode-ray tube may be constructed. Charts and diagrams can explain its operation. Several procedures may be used in the construction of a cathode-ray tube. Directions are available.

The preceding activities are designed for either large or small groups, but it is recommended that small groups be utilized if possible because of difficulty in viewing from a distance.

Another closure activity that makes for an interesting demonstration is the use of resonant Leyden jars to set forth the basic principle of wireless transmission and reception of Hertzian waves. This apparatus may be constructed by a student in independent study and demonstrated to the small groups.

At the very close of the unit the film from PSSC, <u>Mass of the Electron</u>, should be shown.

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Laboratory Manual for Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

White, Harvey E. Laboratory Exercise for Physics. Princeton, New Jersey: D. Van Nostrand Company, 1960.

Reference Books

Bitter, Francis. Current, Fields, and Particles. Cambridge, Massachusetts: M. I. T. Press, 1956.

Holton, Gerald J., and Roller, D. H. Foundation of Modern Physical Science. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1956.

Lehrman, Robert L. Scientific Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1962.

Science Manpower Project Monographs. New York: Columbia University, Teachers College.

Audio-Visual Aids

oulomb's Law. PSSC 0403, 30 min., B & W.

lectromagnetic Waves. PSSC 0415, 30 min., B & W.

rank-Hertz Experiment. PSSC 0421, 20 min., B & W.

lass of the Electron. PSSC 0413, 18 min., B & W.

lillikan Experiment. PSSC 0404, 20 min., B & W.

Many excellent filmstrips are available to the teacher from atalog houses.

UNIT IX

MODERN PHYSICS

Introductory Note

Science has reached into the past, cultivated the present, and looked into the future as it constantly searches for more understanding. The quest brings forth new hypotheses, new theories, and an ever-increasing caution regarding so called "laws." Challenges to twentieth century scientists are the constant extension of learning and the wise utilization of learned concepts.

Each new generation has produced several types of persons. There are those who believe man has reached the pinnacle of learning and must only refine what has been learned beforehand. Some feel that man has only scratched the surface of the vast unknown. There are those who fear that man treads pathways of destruction, and those who live each moment filled with expectation and anticipation of the thrill of discovery.

With the advent of the special theory of relativity and the quantum theory, the scientific world touched a new realm of needed understanding. Old hypotheses, theories, and "laws" were subjected to greater tests. Much of the prior knowledge withstood the tests and was used to explain the new concepts.

The student should be made aware that the special theory of relativity and the quantum theory have no simple design. It, then, fringes on the impossible to discover simple techniques that will give an adequate understanding. The instructor must be cognizant of the danger present in any attempt to simplify materials where simplification might be regarded as ridiculous.

This unit is designed to loosen shackles that society and the educational environment tend to produce.

Unit Objectives

1. To develop an appreciation for modern science and modern scientists.
2. To investigate some of the developmental theories and experiments of modern physics.
3. To increase our understanding of the structure of matter.
4. To introduce an experimental method that obtains results "indirectly."

It is strongly suggested that chapters 32, 33, and 34 from the PSSC textbook Physics be the basic material for this unit of study.

Suggested Outline for Presentation

I. Exploring the Atom
  A. Stages in the development of the atomic theory
  B. The deflection of alpha particles and the Rutherford Model of Atoms
  C. Cloud-chamber photography

II. Modern Concept of Atomic Structure
  A. Heisenberg's Uncertainty Principle
  B. The photoelectric effect
  C. Photons and matter waves
  D. Planck's Quantum Hypothesis
  E. Einstein's Photoelectric Equation
  F. The mass spectrograph
  G. Cathode rays and x-rays

III. Quantum Mechanics
  A. Atomic levels of energy
    1. Determination
    2. Schematic illustrations
    3. Experiment of Franck and Hertz
  B. Quantum numbers
    1. Determination
    2. $E = hf$
       $h = 6.62 \times 10^{-34}$ joule second
       f = vibrations per second
       E = energy comprising a photon
  C. Pauli's Exclusion Principle
  D. Nichols and Hull--pressure of light

IV. Experiments
  A. Michelson-Morley
  B. Millikan oil-drop
  C. The e/m apparatus for measuring the ratio of the charge to the mass of an electron
  D. Scaler radioactivity lab demonstration apparatus

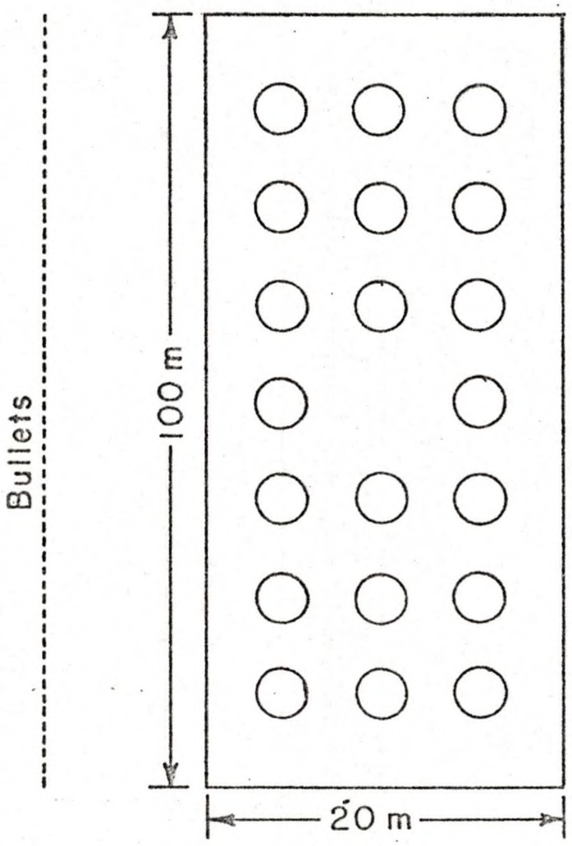
V. Elementary Particles
  A. Known particles and antoparticles
  B. Detection of particles
  C. Properties
  D. $E = mc^2$
  E. Conservation Laws
  F. Forces between elementary particles

VI. Nuclear Physics
   A. Nuclear structure
   B. Measurement of atomic mass
   C. Stable and unstable nuclei
   D. Fission and fusion

Procedural Activities

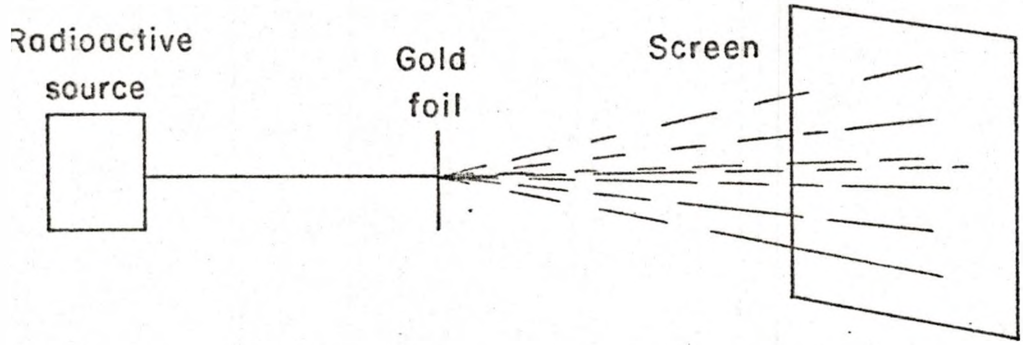
Motivational Techniques: Large Group (Two Modules)

Initially, students can discuss how platinum masses distributed inside a bale of hay could be located without tearing apart the bale. The PSSC text explains the details of this hypothetical experiment. Interest will be enhanced if the apparatus used to probe the interior of atoms with alpha-particle bullets can be demonstrated. The students should be asked to estimate the percentage of bullets that would emerge on the far side of a grove of trees in the problem illustrated below.



If the grove were 20 meters deep and 100 meters long with 20 equal sized trees, we may determine the size of a tree trunk by firing bullets through the grove. Consider the diagram and explain how it may be done. Set a realistic size (suggest 8-10 inches or less) for the diameter of each trunk and estimate the per cent of 22 caliber bullets that would pass through the grove without obstruction. What arrangement of trees would present the greatest obstruction? Bullets should be fired at the grove so that their paths are perpendicular to the earth's surface.

The experiment pertaining to probing atoms with alpha particles hould be illustrated on transparencies.

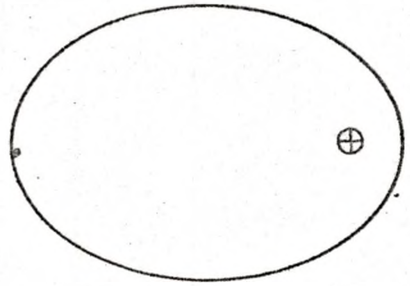


.aboratory: Small Group (Four Modules)

1. The experiment from the PSSC Laboratory Guide for Physics entitled "The Mass of the Electron" should be conducted.
2. The Hoag-Millikan oil-drop apparatus enables the student to measure experimentally the "Charge on the Electron" (Welch No. 0620).
3. The ratio of the "Charge to the Mass of an Electron" may be determined by using an e/m apparatus such as that designed by Bainbridge (Welch No. 0623 and 0623a).

Atomic Structure: Large Group

This introductory lecture should relate chronologically the theories pertaining to atomic models. A thumbnail sketch of scientists who were instrumental in development of atomic theories may be presented by various members of the class. Biographical research should be done during independent study time. During this large group instruction period it is suggested that the film from the PSSC series entitled The Rutherford Atom be shown. In the Rutherford model of any atom, it is assumed that the dimensions of the nucleus are very small when compared to the overall size of the atom.



Even though the linear magnification is in the order of 10^9, the proton making up the nucleus and the electron could not be seen on this scale.

The Rutherford model assumes that the nucleus is a proton with one planetary electron moving in orbit around this unit. An alpha particle is the nucleus in the helium atom. The screening effect of the electrons should be discussed in relation to the electric field.

An excellent demonstration experiment may be conducted by the instructor or capable students showing the scattering of atomic particles. The apparatus (Welch No. 0615) simulates scattering of atomic particles.

The quantum theory had its origin in the study of continuous spectra, but the full realization of its magnitude became more vivid as new methods of conducting quantitative experiments were discovered. As an interest builder, the students may once again observe several spectra while looking through diffraction gratings. The instructor should relate their observations to the quantum theory. If time is available, the students may conduct the following experiment. It may be used as a demonstration.

Objectives: To observe the continuous spectrum emitted by an incandescent solid.

Materials: Bunsen burner, spectroscope or diffraction grating, platinum wire mounted in glass tubing, supports and clamps.

Procedure: Clamp the tubing holding the platinum wire so that it will be firmly held in the non-luminous part of the burner flame. Adjust the spectroscope so that observations might be made by the student.

Observations: As the wire becomes heated, it begins to emit visible light. The spectroscope shows this to be a continuous spectrum. Note: There is a correlation between temperature and the color of light emitted by the glowing platinum wire.

Conclusions: Platinum wire when heated to incandescence produces a continuous spectrum as indicated by the spectroscope. There is a direct relationship between radiation and temperature.

The deflection of alpha particles may well be demonstrated by the use of a cloud-chamber apparatus. It is possible to photograph the tracks of these particles as they move through nitrogen. The deflection of the alpha particle when it collides with a nitrogen atom is clearly illustrated.

Modern Concept of Atomic Structure:
Small-Large Groups

The nature of the material to be covered in connection with this part of the unit makes it best done by lecture, blackboard sketches, and transparencies. The discussion of Kirchhoff and black body radiation, Heisenberg's uncertainty principle, Planck's quantum hypothesis, Pauli's exclusion principle, and Einstein's work, can be extended or limited depending on the instructor's time and knowledge.

A discussion of the photoelectric effect can serve as an introduction to quantum physics and it is suggested that the PSSC film, Photons, be viewed. The discussion should include:

1. The equations for photoelectric emission
2. An explanation of threshold frequency
3. Electromagnetic theory and quantum theory
    a. Failure in relation to photoelectric effect
    b. Success in relation to the photoelectric effect
4. Significance of the quantum theory to modern physics

The PSSC film, Photoelectric Effect, should be viewed.

The photon theory, Roentgen's discovery and use of x-ray photons, the properties of these rays, and the process of production may be discussed. The Compton Effect, its relation to the quantum theory and numerous other topics can be included.

Quantum Mechanics: Large Group (Four Modules)

A definition and explanation of the four quantum numbers that describe the motion of electrons should be determined, defined, and illustrated schematically. The significance of the numbers to the field of physics and chemistry should be explained. The Pauli Exclusion Principle with some of its most potent aspects should be related in the large group and discussed in small groups. The Michelson-Morley experiment should be considered. Experiments in the PSSC Laboratory Guide for Physics that are significant for development of this unit section are:

1. "The Michelson Interferometer"
2. "Waves in a Moving Medium"
3. "Matter Waves"
4. "An 'Ether' Experiment"
5. "Interference in a Moving Medium"

Perhaps, the best PSSC film in the series may be viewed at this time. It is entitled, Frames of Reference.

There is very little that the average secondary student of physics can derive from his limited background that could make Einstein's Special Theory of Relativity understandable. However, the curiosity of the student can be thoroughly aroused by a brief presentation of the mass, energy, and speed relationships. What happens to the mass of an object when its speed of motion approaches the speed of light? Endeavor to arouse the student by discussing: (1) The effects of time dilation, and (2) length contraction.

Discussion of Particles:
Small Group (Two Modules)

In the discussion of electrons, protons, neutrons, nucleons, isotopes, alpha particles, beta particles, and others, it is proposed that each term be defined and then an effort be made to tie them all together. It is only through an overall understanding that the relative importance of the constituent parts can be ascertained.

If equipment is available, some experimentation should be done that involves particle detection devices. Two experiments taken from *Laboratory Experiments for Foundations of Physics* may be conducted.

1. "Determination of the Source of Geiger-Muller Counter Background" (two modules)
2. "Operation of a Geiger-Muller Counter" (two modules)

The concept and calculation of binding energy and the description of nuclear forces should be presented to the students. An explanation of binding energy leads to the discussion of the concepts of fission and fusion. It is suggested that a student in independent study make a demonstration model to illustrate a chain reaction and explain it to the large group.

Discussion: Small Group

1. Chain reactions
2. Half-life
3. Types of radiation
4. Properties of radioactive nuclei
5. Thermonuclear energy
    a. Atomic bomb--simplified explanation of the reaction
    b. Hydrogen bomb--simplified explanation

Experiments taken from the PSSC Laboratory Guide for Physics applicable to this section are:

1. "Simulated Nuclear Collisions"
2. "Randomness in Radioactive Decay."

The following experiments were taken from Laboratory Experiments for Foundations of Physics:

1. "Analysis of Particle Tracks"
2. "Intensity of Gamma Radiation from a Point Source"
3. "Half-life of a Radioactive Source"
4. "Statistics of Events Controlled by Chance."

If possible an expert in the field of radiation should speak to the large group on the effect of radiation on living tissue.

Closure Activities

A field trip to a plant using nuclear-energy or a lecture by an expert in the practical application of nuclear energy in our lives makes an excellent closure.

It is also of great value to secure the services of an individual from the fish, game and wildlife department or commission and have that person relate the magnitude of pollution, including radiation pollution, which we live with presently.

Bibliography

Textbooks

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Lehrman, Robert L. Scientific Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1962.

Lehrman, Robert L. Laboratory Experiments for Foundations of Physics. New York: Holt, Rinehart, and Winston, Inc., 1965.

Lehrman, Robert L., and Swartz, C. Foundations of Physics. New York: Holt, Rinehart, and Winston, Inc., 1965.

Physical Science Study Committee. Advanced Topics. Boston: D. C. Heath and Company, 1963.

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Modern College Physics. Princeton, New Jersey: D. Van Nostrand Company, 1962.

Reference Books

Beiser, Arthur. The Mainstream of Physics. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1962.

Beiser, Arthur. Study Guide for the Mainstream of Physics. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1962.

Born, Max. Einstein's Theory of Relativity. New York: Dover Publications, Inc., 1962.

Castka, Joseph, and Lefler, R. Physics Problems. New York: Holt, Rinehart, and Winston, Inc., 1961.

Ford, Kenneth W. The World of Elementary Particles. New York: Blaisdell Publishing Company, 1963.

Heckman, Harry H., and Starring, Paul W. Nuclear Physics and the Fundamental Particles. New York: Holt, Rinehart, and Winston, Inc., 1962.

Hermias, Sister Mary, and Joecile, Sister Mary. Radioactivity. New York: Holt, Rinehart, and Winston, Inc., 1963.

Holton, Gerald J., and Roller, D. H. Foundation of Modern Physical Science. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1956.

Korsunsky, M. The Atomic Nucleus. Moscow: Foreign Languages Publishing House, 1958.

Livingston, Stanley. High-Energy Accelerators. New York: Interscience Publishers, Inc., 1954.

Orear, Jay. Fundamental Physics. New York: John Wiley and Sons, 1961.

Semat, Henry. Introduction to Atomic and Nuclear Physics. New York: Holt, Rinehart, and Winston, Inc., 1962.

Pamphlets

Comar, C. L. Fallout from Nuclear Tests. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1963.

Corliss, William R. Direct Conversion of Energy. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Corliss, William R. Neutron Activation Analysis. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Corliss, William R. Power Reactors in Small Packages. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Donnelly, Warren H. Nuclear Power and Merchant Shipping. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Glasstone, Samuel. Controlled Nuclear Fusion. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Hogerton, John F. Atomic Power Safety. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Hogerton, John F. Nuclear Reactors. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Kernan, William J. Accelerators. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Lymans, James D. Nuclear Terms. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Martens, F. H., and Jacobson, N. H. Research Reactors. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1965.

Mead, R. L., and Corliss, W. R. Power from Radioisotopes. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Sherrod, John. Popular Books on Nuclear Science. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Audio-Visual Aids

Frames of Reference. PSSC 0307, 30 min., B & W, Resource Center 669.

Interference of Photons. PSSC 0419, 13 min., B & W, Resource Center 670.

Mass of the Electron. PSSC 0413, 18 min., B & W.

Matter Waves. PSSC 0423, 28 min., B & W.

Photoelectric Effect. PSSC 0417, 28 min., B & W.

Photons. PSSC 0418, 25 min., B & W, M.C. 672.

The Rutherford Atom. PSSC 0416, 40 min., B & W.

APPENDIX I

Bibliography

Textbooks

At least one copy of the following texts should be made available to each physics teacher:

Dull, Charles E.; Metcalf, H. Clark; and Williams, John E. Modern Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Lehrman, Robert L., and Swartz, C. Foundations of Physics. New York: Holt, Rinehart, and Winston, Inc., 1965.

Physical Science Study Committee. Physics. Boston: D. C. Heath and Company, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton, New Jersey: Princeton University Press, 1960.

White, Harvey E. Physics, An Exact Science. Princeton, New Jersey: D. Van Nostrand Company, 1959.

Reference Books

American Institute of Physics. Physics in Your High School. New York: McGraw-Hill, 1960.

Beiser, Arthur. The Mainstream of Physics. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1962.

Bitter, Francis. Current, Fields, and Particles. Cambridge, Massachusetts: M. I. T. Press, 1956.

Born, Max. Einstein's Theory of Relativity. New York: Dover Publications, Inc., 1962.

Brinckerhoff, R. F.; Cross, J. B.; and Lazarus, A. Exploring Physics. New York: Harcourt, Brace and World, 1959.

Castka, Joseph, and Lefler, R. Physics Problems. New York: Holt, Rinehart, and Winston, Inc., 1961.

Ford, Leonard. Chemical Magic. Greenwich, Connecticut: Fawcett Publishers, Inc., 1964.

Glicksman, Abraham M., and Ruderman, Harry D. Fundamentals for Advanced Mathematics. New York: Holt, Rinehart, and Winston, Inc., 1964.

Heckman, Harry H., and Starring, Paul W. Nuclear Physics and the Fundamental Particles. New York: Holt, Rinehart, and Winston, Inc., 1962.

Hermias, Sister Mary, and Joecile, Sister Mary. Radioactivity. New York: Holt, Rinehart, and Winston, Inc., 1963.

Holton, Gerald J., and Roller, D. H. Foundation of Modern Physical Science. Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1956.

Korsunsky, M. The Atomic Nucleus. New York: Gordon and Breach, 1964.

Livingston, Stanley. High-Energy Accelerators. New York: Interscience Publishers, Inc., 1954.

Newton, Isaac. Opticks, or a Treatise of the Reflections, Refraction, Inflection and Colours of Light. New York: Dover Publications, Inc., 1952.

Newton, Issac. Philosophiae Naturalis Principia Mathmatica. New York: Citadel Press, 1964.

Orear, Jay. Fundamental Physics. New York: John Wiley and Sons, 1961.

Pitchford, A. Studies in Geometrical Optics. London: MacDonald, 1959.

Science Manpower Project Monographs. Modern High School Physics. 2nd ed. New York: Columbia University, Bureau of Publications.

Scientific Apparatus. Central Scientific Company, 237 Sheffield Street, Mountainside, New Jersey.

Scientific Apparatus. The Welch Scientific Company, 1515 North Sedgwick Street, Chicago 10, Illinois.

Searle, G. F. C. Experimental Optics. Cambridge, England: Cambridge University Press, 1935.

Sears, F. W., and Zemansky, M. W. College Physics. Reading, Massachusetts: Addison-Wesley Publishing Company, 1960.

Semat, H. Fundamentals of Physics. New York: Holt, Rinehart, and Winston, Inc., 1957.

Semat, H. Introduction to Atomic and Nuclear Physics. 4th ed. New York: Holt, Rinehart, and Winston, Inc., 1962.

Thurber, Walter A., and Collette, Alfred T. Teaching Science in Today's Secondary Schools. Rockleigh, New Jersey: Allyn and Bacon, 1964.

Weber, Robert L., et al. College Physics. New York: McGraw-Hill, 1959.

Reference Books (Students)

Andrade, E. N. da C. Sir Isaac Newton. Garden City, New York: Doubleday and Company, Inc., 1954.

Andrade, E. N. da C. Rutherford and the Nature of the Atom. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1964.

Asimov, Isaac. A Short History of Chemistry. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1965.

Bascom, Willard. Waves and Beaches. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1964.

Battan, Louis J. The Nature of Violent Storms. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1961.

Battan, Louis J. Cloud Physics and Cloud Seeding. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Battan, Louis J. Radar Observes the Weather. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Benade, Arthur. Strings and Harmony. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Bitter, Francis. Magnets. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1959.

Bitter, Francis. Mathematical Aspects of Physics. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1963.

Bondi, Herman. The Universe at Large. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Bondi, Herman. Relativity and Common Sense. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1964.

Boys, Charles Vernon. Soap Bubbles. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1959.

Brown, Sanborn C. Count Rumford. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Cohen, Bernard I. The Birth of a New Physics. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Davis, Kenneth S., and Day, John A. Water: The Mirror of Science. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1961.

Dubos, Rene. Pasteur and Modern Science. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Fink, Donald G., and Lutyens, David M. The Physics of Television. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Galambos, Robert. Nerves and Muscles. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Gamow, George. Gravity. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Griffin, Donald. Echoes of Bats and Men. Science Study Series. Garden City, New York: Doubleday and Company, 1959.

Griffin, Donald. Bird Migration. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1964.

Holden, Alan, and Singer, Phyllis. Crystals and Crystal Growing. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Hughes, Donald. The Neutron Story. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1959.

Hurley, Patrick. How Old is the Earth? Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1959.

Jaffe, Bernard. Michelson and the Speed of Light. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Kock, Winston E. Sound Waves and Light Waves. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1965.

Koestler, Arthur. The Watershed: About Johannes Kepler. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

MacDonald, D. K. C. Faraday, Maxwell, and Kelvin. Science Study Series. Garden City, New York: Doubleday and Company, Inc.

MacDonald, D. K. C. Near Zero: The Physics of Low Temperature. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1961.

Ovenden, Michael W. Life in the Universe. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Page, Morris Robert. The Origin of Radar. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Pierce, John R. Electrons and Waves. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1964.

Romer, Alfred. The Restless Atom. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Sandfort, John F. Heat Engines. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Shapiro, Asher. Shape and Flow: The Fluid Dynamics of Drag. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1961.

Stewart, Alec T. Perpetual Motion. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1965.

Van Bergeijk, William A.; Pierce, John R.; and David, Edward E. Waves and the Ear. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Weaver, Warren. Lady Luck, The Theory of Probability. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1963.

Weisskopf, Victor F. Knowledge and Wonder: The Natural World as Man Knows It. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1962.

Wilson, R., and Littauer, R. Accelerators. Science Study Series. Garden City, New York: Doubleday and Company, Inc., 1960.

Laboratory Manuals

Dull, Charles E.; Metcalfe, H. Clark; and Williams, John E. Laboratory Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1969.

Lehrman, Robert L. Scientific Experiments in Physics. New York: Holt, Rinehart, and Winston, Inc., 1962.

Physical Science Study Committee. Laboratory Guide for Physics. Boston: D. C. Heath and Company, 1968.

Periodicals

The Physics Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Physics Today. American Institute of Physics, Prince and Lemon Streets, Lancaster, Pennsylvania, or 335 East 45th Street, New York.

Science and Math Weekly. American Education Publications, 1250 Fairwood Avenue, Columbus, Ohio.

Science News Letter. Science Service, 1719 N. Street, N.W., Washington, D. C.

The Science Teacher. National Science Teachers' Association, 1201 Sixteenth Street, N.W., Washington, D. C.

Scientific American. 2 West Forty-Fifth Street, New York.

Senior Science. Science World, 900 Sylvan Avenue, Englewood Cliffs, New Jersey.

Pamphlets

Comar, C. L. Fallout from Nuclear Tests. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1963.

Corliss, William R. Direct Conversion of Energy. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Corliss, William R. Neutron Activation Analysis. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Corliss, William R. Power Reactors in Small Packages. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Donnelly, Warren H. Nuclear Power and Merchant Shipping. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Glasstone, Samuel. Controlled Nuclear Fusion. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Hogerton, John F. Atomic Power Safety. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Hogerton, John F. Nuclear Reactors. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Kernan, William J. Accelerators. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Lymans, James D. Nuclear Terms. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Martens, F. H., and Jacobson, N. H. Research Reactors. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1965.

Mead, R. L., and Corliss, W. R. Power from Radioisotopes. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Sherrod, John. Popular Books on Nuclear Science. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1964.

Strollberg, Robert. You and TV. Science Research Associates, Inc., 57 West Grand Avenue, Chicago, Illinois, 1955.

Swartz, Clifford E. Microstructure of Matter. USAEC, P. O. Box 62, Oak Ridge, Tennessee, 1965.

APPENDIX II

Teaching Aids: Audio-Visual, Field and Community

Many sound motion pictures are offered without charge by industries and may be utilized in the classroom. A wide variety of lectures and demonstrations, some a bit unusual, entertaining, and interesting, are also available to help solve program planning.

An attempt herein has been made to compose a listing of several of the resource centers and materials outlets for teacher convenience. During the school year, brochures may be received which will update some of the information being presented in the guide, but all materials listed should be at the instructor's disposal.

Requests for items should be made on special order sheets which may be provided by the resource center or department head. Most audio-visual materials should be booked approximately two months in advance to insure securing the order at the proper time. The common period for rentals to be retained by the school varies from three days to one week in duration. A film-card file should be kept by the resource center or by the department head. Audio-visual guides should also be available in the aforementioned places.

The following is a list of films, filmstrips, and records suggested for use in physics classes:

1. Behavior of Gases, PSSC 0115, 15 min., B & W

2. Change of Scale, PSSC 0106, 23 min., B & W

3. Collisions of Hard Spheres, PSSC 0319, 19 min., B & W

4. Conservation of Energy, PSSC 0313, 27 min., B & W

5. Coulomb Force Constant, PSSC 0405, 34 min., B & W

6. Counting Electrical-Charges in Motion, PSSC 0408, 22 min., B & W

7. Crystals, PSSC 0113, 25 min., B & W

8. Definite and Multiple Proportions, PSSC 0110, 30 min., B & W

9. Deflecting Forces, PSSC 0305, 30 min., B & W

10. EMF, PSSC 0430, 20 min., B & W

11. Elastic Collisions and Stores Energy, PSSC 0318, 27 min., B & W

12. Electric Fields, PSSC 0406, 25 min., B & W

13. Electromagnetic Waves, PSSC 0415, 33 min., B & W

14. Electrons in a Uniform Magnetic Field, PSSC 0412, 11 min., B & W

15. Elementary Charges, Transfer of Kinetic Energy, PSSC 0409, 34 min., B & W

16. Elements, Compounds and Mixtures, PSSC 0111, 33 min., B & W

17. Elliptical Orbits, PSSC 0310, 19 min., B & W

18. Energy and Work, PSSC 0311, 28 min., B & W

19. Forces, PSSC 0301, 23 min., B & W

20. Frames of Reference, PSSC 0307, 30 min., B & W

21. Frank-Hertz Experiment, PSSC 0421, 25 min., B & W

22. Free Fall and Projectile Motion, PSSC 0304, 27 min., B & W

23. Inertia, PSSC 0302, 27 min., B & W

24. Inertial Mass, PSSC 0303, 19 min., B & W

25. Interference of Photons, PSSC 0419, 13 min., B & W

26. Introduction to Optics, PSSC 0201, 23 min., Color

27. Long Time Intervals, PSSC 0102, 25 min., B & W

28. Mass of the Electron, PSSC 0413, 18 min., B & W

29. Measuring Large Distances, PSSC 0103, 29 min., B & W

30. Measuring Short Distances, PSSC 0104, 20 min., B & W

31. Mechanical Energy and Thermal Energy, PSSC 0312, 22 min., B & W

32. Millikan Experiment, PSSC 0404, 30 min., B & W

33. Periodic Motion, PSSC 0306, 33 min., B & W

34. Photoelectric Effect, PSSC 0417, 28 min., B & W

35. Photons, PSSC 0418, 25 min., B & W

36. Potential Energy, Part I, PSSC 0431B, B & W

37. Pressure of Light, PSSC 0202, 25 min., B & W

38. Random Events, PSSC 0116, 31 min., B & W

39. The Rutherford Atom, PSSC 0416, 40 min., B & W

40. Short Time Intervals, PSSC 0119, 21 min., B & W

41. Simple Waves, PSSC 0204, 27 min., B & W

42. Sound Waves in Air, PSSC 0207, 35 min., B & W

43. Speed of Light, PSSC 0203, 21 min., B & W

44. Straight Line Kinematics, PSSC 0107, 30 min., B & W

45. Time and Clocks, PSSC 0101, 28 min., B & W

46. Universal Gravitation, PSSC 0309, 31 min., B & W

47. Vector Kinematics, PSSC 0109, 16 min., B & W

48. Vectors, PSSC 0108, 27 min., B & W

The following films can be found in several catalogs. It is recommended that they be purchased by the Physics Department and kept in the Resource Center.

1. Gravity, Weight and Weightlessness, 11 min., B & W

2. Hearing the Orchestra, 13 min., B & W

3. How TV Works, 10 min., B & W

4. Introduction to Physics, 10 min., B & W

5. Light Waves and Their Uses, 11 min., B & W

6. Looking at Sounds, 10 min., B & W

7. Magnetism, 15 min., B & W

8. The Micrometer, 15 min., B & W

9. Molecular Theory of Matter, 11 min., B & W

10. Nuclear Submarine, 12 min., B & W

11. Our Friend the Atom (2 reels), 60 min., Color

12. Preface to Physics, 15 min., B & W

13. Rockets and Satellites, 14 min., Color

14. Simple Machines, 11 min., B & W

15. Sound Waves and Their Sources, 11 min., B & W

16. Speed of Light, 14 min., B & W

17. Strange Case of the Cosmic Rays (2 reels), 60 min., Color

18. Thermodynamics, 11 min., B & W

19. This is Aeronautics, 19 min., Color

20. U. S. Space Pioneer, 10 min., B & W

The following films and taped lectures, provided by the Bell Telephone Company, are applicable to physics:

Films

1. About Time, 60 min., Color

2. Bell Solar Battery, 12 min., Color

3. Coaxial and Microwave Miracles, 11 min., B & W

4. Crystal Clear, 10 min., Color

5. The Far Sound, 26 min., Color

6. Krystallos, 7 min., Color

7. A Missile Named Mac, 10 min., Color

8. Mr. Bell, 30 min., B & W

9. Music in Motion, 18 min., Color

10. Our Mr. Sun, 60 min., Color

11. The Restless Sea, 60 min., Color

12. The Strange Case of the Cosmic Rays, 60 min., Color

13. Talking of Tomorrow, 10 min., Color

14. Tasi the Time Machine, 10 min., Color

15. Telstar, 27 min., Color

16. The Transistor, 10 min., B & W

17. The Unchained Goddess, 60 min., Color

18. A Voice for Mercury, 14 min., Color

19. Wire for Sound, 10 min., Color

Lectures

1. Bell Solar Battery, 20 min.

2. Hop, Skip and Jump in Telephony, 26 min.

3. Mites and Midgets That Make Miracles of Communication, 20 min.

4. The Optical Maser, 35 min.

5. Our Role in Space and National Defense, 30 min.

6. Project Telstar, 25 min.

Other Audio-Visual Sources

Shell Oil Company
149-07 Northern Boulevard
Flushing, New York 11354

Films

1. Approaching the Speed of Sound

2. An Introduction to the Heat Engine

3. Supersonic Flight

4. Transonic Flight

Dr. Robert Overman
Institute for Nuclear Studies
Atomic Energy Commission
Oak Ridge, Tennessee 37830

Three excellent films are available at this source.

Additional Aids and Sources for the Science Teacher

1. American Association for the Advancement of Science
1515 Massachusetts Avenue, N.W.
Washington, D. C. 20005

2. Modern Physics (complete high school physics course on film)
Professor Harvey White, Instructor
Encyclopaedia Britannica Films
Wilmette, Illinois 60091

3. National Aviation Educational Council
1025 Connecticut Avenue, N.W.
Washington, D. C. 20006

4. National Science Teacher's Association
1201 16th Street, N.W.
Washington, D. C. 20006

5. United States Office of Education
Washington, D. C. 20025

Note: Many science leaflets can be obtained from the makers of World Book Encyclopedia, Field Enterprises, Inc., Chicago, Illinois. These are free materials or at a very small cost.

APPENDIX III

Experimental Equipment and Supplies

Equipment List

Quantity	Equipment	Number and Catalog
5	PSSC Four Student Basic Kit Assortment	#5001-Macal

Mechanics

Quantity	Equipment	Number and Catalog
1/4	Acceleration Apparatus (Packard)	#852-W
1/2	Balance, Dial Spring (500 gram)	#4078-W
5/L	Balance, Spring (demonstration)	#4075-W
5/L	Balls, Assorted	#713-735-W
5/L	Ball, Inertia	#545-W
1/L	Bicycle Wheel Gyroscope	#975-W
2/L	Car Ballistics	#0742-W
2/L	Center of Gravity Apparatus	#857-W
2/L	Centrifugal Hoop	#917-W
2/L	Collision Balls Apparatus (with balls and scales)	#701-W
1/2	Density Cylinder	#1162-W
1/2	Force Table	#740-W

Mechanics--Continued

Quantity	Equipment	Number and Catalog
1/2	Hall's Carriage	#818-W
1/2	Inclined Plane and Pulley	#813-W
1/L	Loop-the-Loop Apparatus	#814B-W
2/L	Motor, Lab., Adjustable Speed	#902-W
1/4	Pucks	#3600-Macal
1/2	Pulley and Clamp	#777-W
1/2	Pulleys (assorted)	#756, 758, 760-W
1/2	Recording Timer Kits	#2200-Macal
1/L	Rotator (hand driven with worm drive)	#909A-W
5/L	Second-Law-of-Motion Apparatus	#887-W
1/2	Specific Gravity Specimens	#1137-W
1/L	Stool, Rotating	#570B-W
1/2	Wheel and Axle	#752-W

Key

1/2 = one per each two students

1/4 = one per each four students

2/L = two per laboratory

5/L = five per laboratory

W = The Welch Scientific Co.

C = Central Scientific Co.

Macal = Macalaster Scientific Corporation

Properties of Matter

Quantity	Equipment	Number and Catalog
5/L	Archimedes' Principle Apparatus	#1092-W
2/L	Barometer, Aneroid	#1239-W
1/L	Barometer, Mercury	#1215-W
1/2	Boyle's Law Apparatus	#1078-W
5/L	Browian Movement Apparatus	#4860-W
5/L	Cohesion Plates	#050-W
1/2	Hooke's Law Apparatus	#569-W
10/L	Hydrometers, Light Liquids	#1126-W
10/L	Hydrometers, Heavy Liquids	#1128-W
2/L	Magdeburg Hemispheres	#1509-W
2/L	Pascal's Vases, Simple Form	#1026-W
1/1	Specific Gravity Bottles (25 ml)	#1136-W
1/1	Specific Gravity Bottles (50 ml)	#1136-W
1/1	Specific Gravity Specimens	#1137-W
5/L	Spring, Slinky (coiled) (wave motion demonstration)	#3339-W
5/L	String Vibrator	#3256A-W
5/L	Water Hammer	#1530-W

Heat

Quantity	Equipment	Number and Catalog
2/L	Bottles, Thermos, 1 quart	#1703-W
2/L	Ball and Ring (hand form)	#1661-W
1/1	Bunsen Burners (high BTU)	#4752-W
1/2	Calorimeters (double-walled)	#1689-W
5/L	Conductometer	#1651-W
5/L	Convection Boxes	#1727-W
5/L	Distilling Apparatus	#12750-C
1/2	Generator, Steam	#1625-W
1/2	Linear Expansion Apparatus (Micrometer-screw form)	#1633-W
5/L	Parabolic Reflectors (large)	#1739-W
5/L	Radiation Outfit (rate of cooling apparatus)	#1732-W
2/L	Radiometer (single vane type)	#1733-W
5/L	Specific Heat Specimens (set of five)	#1714-W
1/1	Thermometers, Centigrade (-22^{o} to 110^{o})	#5670-W
2/L	Unequal Expansion (compound bar)	#1663-W

Note: It is strongly recommended that several supply houses be investigated and prices compared for the same piece of equipment.

Wave Motion

Quantity	Equipment	Number and Catalog
2/L	Metronomes	#825-W
2/L	Stroboscopes, White Light	#2153B-W

Light

Quantity	Equipment	Number and Catalog
1/L	Camera, Polaroid 110 B	#229-Macal
1/1	Candles, Paraffin (for optical bench tests)	#3591-W
2/L	Carbon Arc Light Source (with ballast)	#3680K-W
1/L	Chart, Spectrum	#4856A-W
2/L	Color Apparatus (Singerman's)	#3671-W
1/1	Diffraction Gratings (replica)	#86252-C
4/L	Filters, Glass Color (set of eight)	#3661T-W
2/L	Fluorescent Minerals Kit	#638C-W
1/1	Foot-Candle Meters	#3588-W
1/1	Index-of-Refraction Plate (7 cm square and 6 mm thick)	#3494A-W
5/L	Interference Plates	#M5218-W
5/L	Lenses, Achromatic	#3448-C
1/1	Lenses, Mounted (diameter-75 mm-convex)	#3500-W
1/1	Lenses, Mounted (diameter-75 mm-concave)	#3500-W

Light--Continued

Quantity	Equipment	Number and Catalog
1/2	Light Sources (for optical benches)	#3570-W
2/L	Lucite Rod, Coiled	#3530-W
2/L	Microwave Optics Ed. Set (Mark II)	#2643-W
1/1	Mirrors, Plane (10 x 15 cm)	#3510-W
1/2	Mirror, Spherical (10 cm diameter)	#3516-W
5/L	Mirrors (concave-10 cm)	#3525-W
2/L	Multi-Image Apparatus	#3526-W
1/2	Optical Benches (get better type if possible)	#3600-W
2/L	Optical Disk (multiple-slit adjuster and accessories set)	#3675-W
1/2	Photometer Head (Bunsen)	#3578-W
5/L	Polaroid Film Disks (plastic-rimmed, set of two)	#3707-W
1/2	Prisms (10 cm length)	#3464-76-W
1/L	Projector	#3962C-W
5/L	Refraction Tank	#3500-W
1/L	Sodium-Arc Light Source	#3720B-W
1/L	Mercury Vapor Light Source	#3721-W
1/2	Supports (meter stick with holders for multiple candles)	#3566-67-W
2/L	Ultraviolet Light Sources	#638A-W

Light--Continued

Quantity	Equipment	Number and Catalog
1/2	Monochromatic-Flame Attachment, Cup Type	#3720-W
1/L	Helium Spectrum Tube	W
1/L	Argon Spectrum Tube	W
1/L	Neon Spectrum Tube	W
1/L	Hydrogen Spectrum Tube	W
1/L	Chlorine Spectrum Tube	W
1/L	Mercury Spectrum Tube	W
1/L	Oxygen Spectrum Tube	W
1/L	Nitrogen Spectrum Tube	W

Sound

Quantity	Equipment	Number and Catalog
2/L	Air-Jet Attachment (for siren disk)	#953-W
2/L	Crova's Disk	#942-W
2/L	Cubical Mirror	#926-W
2/L	Doppler's Principle Apparatus	#964-W
2/L	Galton's Whistle	#3332-W
2/L	Kundt's Apparatus	#3302-W
2/L	Manometric Flame (Koenig's)	#963-W
1/L	Organ Pipes (open-set)	
1/L	Organ Pipe (sliding piston)	#3272-W

Sound--Continued

Quantity	Equipment	Number and Catalog
1/2	Resonance Tube Apparatus (resonance reservoir type)	#3308-W
2/L	Siren Disk	#949-W
5/L	Sonometers (multiple stringed metal framed-adjustable tension)	#3350-W
2/L	String Vibrator (120 vps)	#3256-W
2/L	Sympathetic Tuning Forks (with adjustable slides and mounted)	#3246-W
2/L	Tuning Forks (ton alloy) 128, 512, 1024, 2048 C D E F two sets G A B	#3229A-W
1/L	Vibrograph (with tuning fork)	#3260C-W

Electricity and Electronics

Quantity	Equipment	Number and Catalog
1/L	Audio Amplifier and Speaker	#80575-C
1/L	Audio Oscillator	#80593-C
1/L	Battery Charger (6 V and 12 V)	#79559-C
20/L	Battery, Dry Cells (1.5 V)	#79145-C
1/5	Battery, Storage (6.0 V)	#79482-C

Electricity and Electronics--Continued

Quantity	Equipment	Number and Catalog
2/L	Capacitance Boxes High and Low Ranges	 #2152B-W #2152C-W
1/L	Cathode Ray Tube (deflection)	#2145-W
1/L	Cathode Ray Tube (rotating wheel)	#2145A-W
1/L	Cathode Ray Tube (cross)	#2145B-W
2/L	Coil, High Frequency	#80730-C
1/2	Coil, Induction	#79800-C
1/2	Coils, Primary and Secondary	#79750-C
1/1	Compasses, Magnetic (45 mm)	#78430-4-C
1/2	Connecting Cord Assortment	#84098-C
10/L	Connecting Wire Sets	#2978-C
2/L	Discharger (jointed arms)	#78975-C
1/4	Demonstration Cell (Gotham)	#79330-C
2/L	Electromagnet (lab. model)	#79639-C
5/L	Electrolysis Apparatus (Hoffman's)	#81200-C
2/L	Electrophorus Demonstration	#78676-C
1/2	Electroscopes	#78705-C
1/L	Electrostatic Generator (Van de Graaf)	#78688-C
5/L	Exciting Pad, silk	#78635-C

Electricity and Electronics--Continued

Quantity	Equipment	Number and Catalog
1/2	Exciting Pad, wool felt	#78630-C
2/L	Flashlight	#84461
1/2	Friction Rods (hard rubber, solid)	#78620-C
1/2	Friction Rods (pyrex glass, solid)	#78605-C
1/4	Galvanometer, Lecture Table	#82133-C
1/4	Galvanometer, Weston Model #375	#82110-C
1/4	Headphones, Double	#80795
1/4	Key, Single Contact	#84210-C
1/4	Lamp-Board Rheostat, 5 socket	#2424-W
2/L	Leyden, Jar, large	#78915-C
1/1	Magnet, Bar (alnico)	#78288-C
1/4	Magnet, Lifting Heavy Duty	#79647-C
1/4	Magnetic Needle (dipping)	#78425-C
2/L	Magnetizer	#1844-C
1/4	Magneto Electric Generator	#79895-C
1/4	Magnetometer MH Measurement	#78485-C
1/2	Magnet-U-shaped	#78340-C
1/2	Meters, A.C. Am-range 0-25 amp	#82426-5-C
1/2	Meters, A.C. Volt-triple range, 0-30, 0-15, 0-150	#82642-2-C

Electricity and Electronics--Continued

Quantity	Equipment	Number and Catalog
2/L	Meters, D.C. Am-single range 0-50 milliamps	#82483-1-C
1/2	Meters, D.C. Volt-triple range, 0-1.5, 0-3, 0-30	#82481-1-C
1/2	Meters, D.C. Volt-triple range, 0-1.5, 0-15, 0-115	#82486-2-C
2/L	Meter, Volt-ohm-mil am	#82461-C
2/L	Microphone Connectors	#84091-C
1/2	Motors, St. Louis	#79945-C
2/L	Microphone, Hand and Table, ceramic	#80809-C
2/L	Multimeter, Demonstration	#3065-W
2/L	Oscillioscope, Cathode Ray five inch	#71556-C
2/L	Photoelectric Demonstration Set	#80934-C
1/2	Pith Balls, assorted colors	#78645-C
2/L	Power Supply 0-500 volts, D.C.	#79552-C
2/L	Power Supply High Voltage, D.C. 0-5000	#79572-C
1/2	Power Supply Low Voltage, A.C.-D.C.	#79549-C
2/L	Radio Demonstration Outfit	#80435-C
2/L	Radio Transmitter Demonstration	#2621-W
2/L	Receiving Antenna	#80441-C

Electricity and Electronics--Continued

Quantity	Equipment	Number and Catalog
1/2	Rheostats Air-Cooled, 2.8 ohms	#82910-17-C
1/2	Rheostats Air Cooled, 11 ohms	#82910-14-C
2/L	Solar Energy Demonstration Kit	#81090-C
1/1	Switch, Knife, Single Pole, Single Throw	#84315-C
2/L	Thermoelectric Pair	#81060-C
1/4	Transformer Rheostat Voltage Control	#80295-3-C
1/2	Transistor Analyzer	#80390-C
1/4	Vacuum Tube Volt-Ohmmeter	#82465-C
1/3	Wheatstone Slide-Wire Bridge Assembly	#2808-W

Modern Physics

Quantity	Equipment	Number and Catalog
2/L	Alpha Ray Tip	#71021-C
2/L	Beta Ray Capsule	#71022-C
2/L	Cathode Ray Tubes	
	1. Kinetic energy of particles	#71705-C
	2. Fluorescent effects	#71560-C
2/L	Chart of Atoms on Spring Roller	#4854A-W
2/L	Diffraction Grafting, replica	#86763-C
2/L	Diffusion Cloud Chamber, with clearing field	#71850-C
8/L	Dosimeter, direct reading	#650-Macal

Modern Physics--Continued

Quantity	Equipment	Number and Catalog
2/L	Dosimeter Charger, transistorized	#71251-C
2/L	Microwave Apparatus, 3 cm	#80470-C
2/L	NTS-II Nuclear Training System	#71293-C
2/L	Spectrometer, student	#86970-C
2/L	Spectrum Chart	#12068-C
2/L	Spectrum Chart	#12068-C
8/L	Spinthariscope	#71205-C

Miscellaneous

Quantity	Equipment	Number and Catalog
2/L	Air Pump Plate (with rubber pad)	#1426-W
1doz/1	Asbestos, Squares	#5906-W
1/2	Balance, Harvard Trip (with stain-less steel pans, single-beam)	#4045-W
2/L	Balance, Spring (50-pound capacity)	#4072-W
1/2	Balance, Triple-beams (low form)	#4048-W
	Beakers, Griffin low form - 100, 250, 400, 600, 1000, 2000 ml number depends on program	#4516P-W
1/4	Caliper, Micrometer Metric	#40-W
1/4	Caliper, Vernier	#46-W
2/L	Cart, Laboratory	#54-W
1/1	C Clamp	#59-W

Miscellaneous--Continued

Quantity	Equipment	Number and Catalog
2/L	Charts, Physics with Portable Tripod	#1575-W
1/1	Clamp, Lever (knife edge)	#745-W
1/2	Clamp, Meter Stick, parallel type	#4325-W
1/2	Clamps and Tongs, various types	
1/5	Clock, Stop, Electric	#824H-W
3/L	Counter, Revolution Handheld	
12/L of each	Cylinder, Graduated Tuttle Short form	#16110-5 #16110-100-C
4 each of 2 sizes per laboratory	Funnel, short or long stem, fluted	
2 each/ L	Jar, Bell, High Solid Top High Open Top	#1457-W #1477-W
1/1	Meter Stick (maple)	#153-W
2/L	Pump, Vacuum and Pressure (motor driven with pump plate)	#1410-W
1/1	Rods and supports	
2/L	Stroboscope Range: 60-14, 400 RPM	#74675-C
	Tubes, Test Various Sizes depends on program	
1/1	Weight Hangers	#785-W

Miscellaneous--Continued

Quantity	Equipment	Number and Catalog
1/2	Weights, Metric (1 g to 1000 g)	#4158A-W
1/2	Weights, Slotted (metric, large)	#4180A-W

Supplies List

Quantity	Equipment	Number and Catalog
10 lb/L	Acetamide, Pure	
5 pt/L	Acid, Hydrochloric	
1 pt/L	Acid, Oleic	
10 lb/L	Acid, Sulfuric	
2 gal/L	Alcohol, Ethyl Denatured	
2 gal/L	Alcohol, Methyl	
10/L	Bologna Vials	
10/L	Ice Bomb	
10 lb/L	Camphor, Gum	
10 lb/L	Carbon Tetrachloride	#1670
4 lb/L	Copper Metal, Shot	
2 bags/L	Corks, Assorted Sizes	
18 oz/L	Cement, Pliobond	#6864-W
6 lb/L	Cupric Sulfate, Powder Technical	
10 oz/L	Lycopodium Powder	
16 lb/L	Mercury Tech.	
2 lb/L	Paraffin, Solid	
1 lb/L	Shellac, bleached dry	
	Tubing, Glass Various Sizes depends on program	
	Tubing, Rubber and Plastic 50 ft. of each depends on program	

BIBLIOGRAPHY

Books

Allen, Dwight W., and Bush, Robert N. New Design for High School Education. New York: McGraw-Hill Book Company, 1964.

Anderson, Robert H. Teaching in a World of Change. New York: Harcourt, Brace and World, Inc., 1966.

Anderson, Vernon E. Curriculum Improvement. New York: The Ronald Press Company, 1956.

Bair, Medill, and Woodward, Richard G. Team Teaching in Action. Boston: Houghton Mifflin Company, 1964.

Beggs, D. W. Decatur-Lakeview High School: A Practical Application of the Trump Plan. Englewood Cliffs, New Jersey: Prentice-Hall, 1964.

Bennis, Warren G.; Benne, Kenneth D.; and Chin, Robert. The Planning of Change. New York: Holt, Rinehart and Winston, 1961.

Berman, Louise M. New Priorities in the Curriculum. Columbus: Charles E. Merrill Publishing Company, 1968.

Bochenski, I. M. Contemporary European Philosophy. Los Angeles: University of California Press, 1956.

Borg, Walter R. Educational Research: An Introduction. New York: David McKay Company, Inc., 1963.

Brown, B. Frank. The Appropriate Placement School: A Sophisticated Nongraded Curriculum. West Nyack, New York: Parker Publishing Company, Inc., 1965.

Brubacher, John S. Modern Philosophies of Education. 3rd ed. New York: McGraw-Hill Book Company, 1962.

Bush, Robert N., and Allen, Dwight W. New Design for Secondary Education. New York: McGraw-Hill Book Company, 1964.

Carlson, Richard O. Adoption of Educational Innovations. Eugene, Oregon: University of Oregon, 1965.

Dewey, John. Democracy and Education. New York: The Macmillan Company, 1964.

Douglass, Harl R. Trends and Issues in Secondary Education. New York: The Center for Applied Research in Education, Inc., 1962.

Faunce, Roland C., and Bossing, Nelson L. Developing the Core Curriculum. 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1958.

Fliegler, Louis A., ed. Curriculum Planning for the Gifted. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964.

Gall, Morris, and Hicks, William V. Modern Secondary Education. New York: American Book Company, 1964.

Gross, Ronald, and Murphy, Judith, eds. The Revolution in the Schools. Chicago: Harcourt, Brace and World, Inc., 1964.

Hass, Glen, and Wiles, Kimball, eds. Readings in Curriculum. Boston: Allyn and Bacon, Inc., 1965.

Krug, Edward A. The Secondary School Curriculum. New York: Harper and Row, Publishers, 1960.

Lieberman, Myron. The Future of Public Education. Chicago: University of Chicago Press, 1960.

Lippitt, Ronald; Watson, Jeanne; and Westley, Bruce. The Dynamics of Planned Change. Chicago: Rand McNally and Co., 1961.

Manlove, Donald C., and Beggs, David W., III. Flexible Scheduling. Bloomington, Indiana: Indiana University Press, 1965.

Neagley, Ross L., and Evans, N. Dean. Handbook for Effective Curriculum Development. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967.

Oliver, Albert I. Curriculum Improvement. New York: Dodd, Mead and Company, 1965.

Polos, Nicholas C. The Dynamics of Team Teaching. Dubuque, Iowa: Wm. C. Brown Company, 1965.

Rockefeller Brothers' Fund. "The Pursuit of Excellence: Education and the Future of America." Panel Report V of the Special Studies Project. New York: Doubleday and Company, Inc., 1958.

Saylor, J. Galen, and Alexander, William M. Curriculum Planning. Chicago: Holt, Rinehart and Winston, Inc., 1966.

Scott, Walter M., S. J., ed. "Declaration on Christian Education." The Documents of Vatican II. New York: Guild Press, 1966.

Steeves, Frank L., ed. The Subjects in the Curriculum. New York: The Odyssey Press, Inc., 1968.

Stutz, Rowen C., and Merrel, Russell G., eds. Western States Small School Project. Denver, Colorado: State Department of Education.

Teilhard de Chardin, Pierre. Building the Earth. Wilkes-Barre, Pennsylvania: Dimension Books, 1965.

Thorton, James W., Jr., and Wright, John R., eds. Secondary School Curriculum. Columbus, Ohio: Charles E. Merrill Books, Inc., 1963.

Thorton, James W., Jr., and Wright, John R. Secondary School Curriculum Development. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967.

Trump, J. Lloyd, and Boynham, Dorsey. Guide to Better Schools--Focus on Change. Chicago: Rand-McNally Company, 1961.

Trump, J. Lloyd, and Miller, Delmas F. Secondary School Curriculum Planning. Boston: Allyn and Bacon, Inc., 1968.

Ulich, Robert, ed. Three Thousand Years of Educational Wisdom. Cambridge, Massachusetts: Harvard University Press, 1954.

Wiles, Kimball. The Changing Curriculum of the American High School. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

Periodicals

Allen, Dwight W., and Moore, R. B. "Nothing Ventured, Nothing Gained." California Journal of Secondary Education, XXXV (February, 1960), pp. 91-93.

Allen, Dwight W. "Elements of Scheduling a Flexible Curriculum." Journal of Secondary Education, XXXVIII (November, 1963), pp. 84-91.

Allen, Dwight W., and DeLoy, D. "Stanford's Computer System Gives Scheduling Freedom to Twenty-Six Districts; Stanford School Scheduling System." Nation's Schools, LXXVII (March, 1966), p. 124.

Brauer, Oscar L. "Something Dangerously New in Physics Teaching." Science Education, IIIL (October, 1963), pp. 365-71.

Bush, R. N. "Decision for the Principal: Hand or Computer Scheduling?" National Association of Secondary School Principals Bulletin, IIL (April, 1964), pp. 141-46.

D'Antuono, A., and McCallum, W. A., Jr. "Constructing the Master by a Computer." National Association of Secondary School Principals Bulletin, IL (October, 1965), pp. 58-65.

Ferris, Frederick L., Jr. "An Achievement Test Report." The Science Teacher, XXVI (December, 1959), pp. 574-81.

Finlay, Gilbert. "Summary of Judgments Made by Teachers." The Science Teacher, XXVI (December, 1959), pp. 579-81.

"Flexible Scheduling: An Approach to Individualizing Instruction in Secondary Schools: A Symposium." Journal of Secondary Education, XXXVI (October, 1961), pp. 336-84.

Forosma, J. W. "New High School With a New Look." North Central Association Quarterly, XXXVII (Spring, 1963), pp. 293-97.

Glatthorn, A. A., and Ferderbar, J. E. "Independent Study for All Students: Abington High School, North Campus." Phi Delta Kappan, IIIL (March, 1966), pp. 379-82.

Haggerson, N. L., and Smith, N. B. "Seventy-Minute-Period Schedule Contributed to More Effective Utilization." National Association of Secondary School Principals Bulletin, XXXXVI (April, 1962), pp. 51-57.

Hofmann, E. B. "Brookhurst Plan, an Experiment in Flexible Scheduling." National Education Association Journal, LIV (September, 1965), pp. 50-52.

Holland, B. H., and Anderson, L. W. "What is the Most Effective Way of Arranging the Length and Use of the Class Period." National Association of Secondary School Principals Bulletin, XXXXIII (April, 1959), pp. 158-63.

Holtan, Gerold. "Project Physics. A Report on Its Aims and Current Status." The Physics Teacher, V, No. 5 (May, 1967), pp. 198-211.

Holzman, A. G., and Turkes, W. R. "Optimal Scheduling in Educational Institutions." U. S. Office of Education, Cooperative Research Project No. 1323. Pittsburgh, Pennsylvania: University of Pittsburgh, 1964.

Howard, E. R. "The School of the Future--Now." National Association of Secondary School Principals Bulletin, XXXXVI (May, 1962), pp. 258-67.

Howard, E. R. "Flexible Scheduling." North Central Association Quarterly, XL (Fall, 1965), pp. 208-13.

Leigh, T. G. "Big Opportunities in Small Schools Through Flexible Modular Scheduling." Journal of Secondary Education, LI (March, 1967), p. 178.

"New Designs for the Secondary School Schedule: A Symposium." California Journal of Secondary Education, XXXV (February, 1960), pp. 91-134.

Rutherford, James F. "Flexibility and Variety in Physics." The Physics Teacher, V, No. 5 (May, 1967), pp. 224-29.

Shanus, Rosemary; Bouchard, Sharon; and Toupin, Harold O. "Modular Scheduling; How Much Fact--How Much Illusion?" Business Education World (November, 1966), p. 14.

Storlie, T. R. "Evaluating Flexible Scheduling." Educational Leadership, XXV (November, 1967), p. 183.

"The Man of the Year." Time, LXXXIX (January 6, 1967), pp. 22-23.

Trump, J. Lloyd. "Images of the Future." National Association of Secondary School Principals (1959).

Trump, J. Lloyd. "Flexible Scheduling: Fad or Fundamental." Music Educators' Journal, LII (November, 1965), p. 61.

Papers

Glatthorn, Allan A. "Learning in the Small Group," Institute for Development of Educational Activities, Melbourne, Florida, 1966. (Mimeographed.)

Harvard University, Harvard Project Physics. "Teacher's Newsbrief," Cambridge, Massachusetts, March 1, 1969. (Mimeographed.)

Stanford University, School of Education Conference. "Flexible Scheduling: A Reality," California, 1966. (Mimeographed.)

Stanford University, School of Education Conference. "Individualized Instruction," California, 1966. (Mimeographed.)

Stanford University, School of Education Conference. "Small Group Instruction: A New Challenge," California, 1966. (Mimeographed.)

Paperbacks

Johnson, Robert H., Jr. Rx for Team Teaching. Minneapolis, Minnesota: Burgess Publishing Company, 1968.

Kuhlen, Raymond G., ed. Studies in Educational Psychology. Waltham, Massachusetts: Blaisdell Publishing Company, 1968.