M A P

MODULAR APPROACH TO PHYSICS:

THE DEVELOPMENT OF A HUMANISTIC, INDIVIDUALISTIC PHYSICS CURRICULUM

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"It is clear at present to everybody that it is precisely the progress of physics that determines the possibilities of development in a wide range of sciences, from cosmology to biology, and medicine. It is physics that determines to a large extent the foundations of our outlook as well as possibilities and limits of our practical activities. One cannot be called a specialist or, for that matter, an educated person unless one is familiar with a certain range of ideas and facts in the sphere of physics."

"In many countries, education in physics both for non-specialists and for future specialists, is unsatisfactory. In all countries, improvement is essential at some levels of teaching. Experiments have been initiated in some countries to try to find ways to make improvements; we welcome and encourage such experiments. They are particularly necessary and important at the level of secondary schools or their equivalent. Experiments and solutions will probably take different forms in different countries."

The above quotations are from the International Education in Physics. Proceedings of the International Conference on Physics Education, UNESCO HOUSE, Paris (July 18 - August 9, 1960), the MIT Technology Press, and John Wiley and Sons, New York, New York, 1960.

"In our view, physics is an essential part of the intellectual life of man at the present day .... Studying physics and the physicist's method of acquiring and evaluating knowledge should therefore be regarded as a necessary part of the education of all children."

......From a resolution adopted at the above conference.

ABSTRACT

With the increasing complexity of our rapidly changing technological society, our present educational system has found itself become more and more obsolete, and in need of a major redefinition of goals. The development of the new Physics Pilot Project as designed in this paper was the result of the desire on the part of the author to seek a better deal for a high school physics program. The pilot project proposes to change the present method of instruction in the direction of a modular, learner oriented curriculum with the ultimate objective being the humanistic course, better suited to the needs and capabilities of students with varying abilities and aptitudes.

This comprehensive pilot project draws upon the past and present research in the area of physics curriculum development in order to maximise individual instruction by presenting it in a modular form.

The pilot project was designed and implemented in the school where the author teaches. The study carried out for the purpose of developing this pilot project describes the project objectives, the evaluation procedures and the outcomes of the program. There is also a comparison with the traditional approach to physics teaching.

As a result of the development of the pilot project as outlined in this paper, a number of specific recommendations concerning the adoption and implementation of the program on a province wide basis have been made.

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CHAPTER I

INTRODUCTION

Physics today has become a major science, because much of what goes on around us in the world is governed by the laws of physics. The rapid advances made by physicsts since the turn of the century have helped man probe into the mysteries of nature. Today's world is the world of rockets, satellites, computers, and supersonics. It is a world where automation and miniaturization are already controlling man's future life.[1]

Modern technological developments have made the teaching of physics a fascinating experience for the teacher and the student alike.

> "It is inconceivable that in the modern technological age, it could be seriously disputed that sciences should be an essential part of a broad training to be given to all children up to about the age of sixteen - a training that is not intended to prepare them for any particular occupation that we can devise for their entering into the adult world. Physics is the most fundamental of sciences and therefore is clearly essential. Our view does not rest upon the obvious usefulness of physics in a technological world. On the contrary, we have stressed that the claim of physics to be part of education of all children stems from the place that the subject occupies in the intellectual heritage to which we seek through education to introduce our children."[2]

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1. R. K. Goyal, "Some Reflections on Physics Teaching in the Secondary Schools of India and America," unpublished M.N.S. thesis, Arizona State University, May 1967, p. 1.

2. "Why Teach Physics," International Education Conference on physics in general education, Brazil, M.I.T. Press, Mass., 1964, p. 3.

At the present time, physics is suggested to be an optional subject in practically every high school in this province. From the point of view of an average student, it is also considered to be one of the most dreadful of all the subjects. Those students who do decide to take up the study of physics, are, in most cases, apprehensive of the final outcome as far as the results are concerned. In other cases, the students are in doubt as to the reasons for their taking up the study of physics.

In either case, the trends in physics enrollment over the past several years point towards declining physics enrollments - ranging anywhere from 5% to 10% of the total high school population. The relative unpopularity of physics is not because of the nature of the subject itself. No area of study has more application to everyday living than the subject of physics. No other subject deals with more exciting ideas. The fault seems to lie in the goals of the courses offered and the wrong emphasis being placed on some areas of the subject as compared to others which have more relevance in the light of changing concepts of everyday life, which in turn are being brought about by the changing technology.

All of this poses serious problems for the physics teacher. With the wealth of materials around him, the teacher is often faced with the problem of selecting the most vital concepts to present to his students. In response to this challenge, scientists and teachers have sought out new curricula and methods of teaching physics. The results encompass a complete overhaul of the various aspects of physics teaching, including aims and objectives of physics instructions, curriculum development, teaching methods, laboratory work and teacher training.

In the light of these developments, it is significant to note that almost all of these changes and innovations have taken place in the United States of America, with practically no evaluation being done in Canada. In most cases, these courses are adopted as such without much thought being given to their ultimate relevance or irrelevance to those areas of the country where these courses are going to be taught.

PURPOSE

The author wishes to pursue this study for the following reasons:

1. To study the relationship between physics course offerings and the declining physics enrollments.

2. To undertake a complete and thorough survey of the recent developments in the field of curriculum development in physics, notably the new Project Physics, as well as other course offerings.

3. To do a pilot study leading to the development of an integrated course of study better suited to the needs of students at various levels - a course that would seek to achieve a synthesis between the traditional aspects of physics teaching on one hand, and the social, humanistic, historical, and cultural aspects of it on the other.

4. Finally, to place in the hands of the physics teachers of this province a comparison of the various innovative techniques being utilized in individualizing physics instruction, for the purpose of enabling them to choose the best possible approach that would suit the needs of their students.

JUSTIFICATION FOR THE STUDY

Although a number of research papers dealing with a wide variety of studies relating to various aspects of physics teaching and curriculum development are available, all of these were carried out in the United States.

As far as the province of Manitoba is concerned, there have been general studies carried out about the improvement and reorganization of the secondary schools, the most recent example being that of the report of the Core Committee established by the province. A careful and thorough search convinced the author that no such study dealing with the subject of physics had ever been carried out thus far. The present study would be the first such attempt to be made in this direction.

QUESTIONS TO BE CONSIDERED BY THIS STUDY

It is expected that this study would help provide answers to the following questions:

1. What are the curriculum factors which may be responsible for the declining physics enrollments?

2. Should there be one or more than one course available for the teaching of physics?

3. What are the changes needed for the teaching of physics and do these changes meet the needs and standards that are relevant to the truly modern curriculum development concepts?

4. Should a new course/courses prepare students for university entrance or should there be a general physics course/courses that should form a part of a general high school program of studies for all students?

CHAPTER 2

REVIEW OF LITERATURE

GENERAL CURRICULUM DEVELOPMENT PATTERNS IN PHYSICS

Education in the North American continent is undergoing a period of rapid change. Perhaps, it would be no exaggeration to say that what we are witnessing today concerning education, is nothing short of a revolution. Each year that passes by sees some new and even drastic changes being brought about in the average secondary school of today. No aspect of education is under more careful scrutiny and criticism than the high school curriculum.

In any secondary school, the curriculum is the heart of the school. Everything else, such as the building, instructional and administrative staff and instructional materials are meant for just one purpose, that of implementing the curriculum. Practically any and every kind of activity that goes on within the school revolves directly or indirectly around the curriculum or some aspect of it.

It is not surprising, therefore, that constructing and reorganizing curriculum of secondary schools has always been and still is, more than ever before, a major concern of all those concerned with providing quality education for students in our schools. The process involves many continuing problems which are complicated because there are many concepts of curriculum which cause disagreement as to its functions, what should be included, and how the content should be organized. Therefore, experts in the field of curriculum development have defined curriculum in different terms.

The reasons for such a wide ranging shift in current curriculum patterns stem from a host of factors. Perhaps, the most important of such factors is a marked difference in what was believed to be, only decades ago or so, too much emphasis on subject-centered curriculum to what is now the talk of the day - a humane curriculum, i.e., a curriculum that would lay greater emphasis upon the humanistic aspects of curriculum besides providing for individualized instruction.

CURRICULUM DEFINED

Before attempting to pursue in detail the various curriculum patterns in general, it is necessary to have a careful look at what the term "curriculum" means.

A prevailing definition of curriculum is that it consists of all the learning experiences a student can have at school. This definition includes all of the courses of study, the student activities, and the learning experiences connected with the entire school environment. This definition is so comprehensive that it does not give the direction in which one should proceed because it does not provide a basis for determining what experiences the students should have.

But definitions which suggest which types of activities should be provided are preferable. Defined in this manner, the curriculum consists of the learning activities and experiences which have been selected to achieve desired educational goals. This would include the entire instructional program, although it would not include certain elements of the curriculum of a particular student or a group of students. The curriculum for an individual student would include the learning activities planned especially for him, selected from the total resources available and such learnings as may be experienced incidentally.

The term also refers to courses of study provided for groups of students who have specific interests, and needs in common, such as the college oriented group. Thus, a carefully planned sequence of courses leading to a major, or to entry into an occupation or advanced study may be defined as curriculum.

Curriculum includes not only the courses of study designated by a general or a specific title, such as science, mathematics, English, as general terms, or algebra, physics, speech, as specific terms, but also includes the content of each of these courses of study.[3]

CURRICULUM DEVELOPMENT - CRITERIA

Development of a suitable curriculum is a very delicate and at the same time a very demanding task. Before embarking upon a curriculum development project of any kind, standards are needed to determine what courses should be offered by a given school and also what specific learning experiences should be included in each. Again, criteria for content selection are based upon and derived from educational philosophy, theories of learning, various approaches related to the development of the curriculum. Most important of all, the aims and objectives, or for that matter, the goals of what type of a curriculum is wanted for a particular school or group of schools have to be borne in mind.

The purpose of this paper is not to dictate solutions but to

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3. Rudyard K. Bent and Adolph Unruh, Secondary School Curriculum, D. C. Heath & Co., Mass., 1969, p. 2.

trace the various curriculum development patterns, their implications in relation to the current thinking in the field of education, and to present alternatives - all of which are necessary to bring about the dramatic changes necessary to provide a quality education that is better suited to the needs of the individual as well as the society in which he has to function. In other words, we need a curriculum that would create competent and self directed individuals who can then work to cure the ills of the society as a whole. The challenge to all of us - teachers, students, parents and administrators is to discuss the issues, try out the various solutions, and finally come up with the answers.

TRADITIONAL PATTERNS IN CURRICULUM DEVELOPMENT

Hardly any other field of educational development has attracted as much attention as the field of curriculum. Even today, anyone reviewing the various developments that have taken place in the field of education finds himself bewildered with conflicting currents of opinion regarding curriculum development. Basically, there are two main areas of dispute in this field:

> A. "A strongly conflicting force tending to come from the profession rather than taxpayers urges that schools become more humane. This force, appealing to most of us, since to be inhumane is sinful indeed, pushes us back to the child centered informal schools of the 1920's and 1930's. Certainly, we do want to personalize curriculum options and individualize instruction in more effective ways than allowing children to progress at varying rates through uniform sequences - but it is easier to prescribe than to personalize."[4]

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4. William M. Alexander, Curriculum Planning As It Should be, Eric Cat. No. ED-061 585, An address presented at an ASCD Conference on "The School of the Future," Chicago, Ill., 1971, p. 1.

B. "Still another force comes from angry critics, parents and students who would abandon public schools, letting the curriculum for each child be whatever the home, the media, the community, or perhaps the alternative form of schooling selected, would have it be. This force tends to be more negative than positive and it is indeed difficult to incorporate its proposals into a plan for improving the curriculum. Yet the criticisms of inefficiency, bureaucracy, learner abuse, and mindlessness sting, and underline the seriousness of need for far more effective curriculum planning than now generally exists."[5]

This seems to reveal a harsh fact that past theories and the process of curriculum planning have not adequately served the educational process. Many experts and professionals, who are more deeply associated with the process of curriculum planning and development, find themselves somewhat disillusioned.

What, then, are the reasons and factors behind this sad state of affairs existing in the field of curriculum development? Before going any further, one must take into consideration the aims and objectives of any type or form of curriculum development designed to ensure quality education for children in the secondary schools of today.

CURRICULUM DEVELOPMENT - AIMS AND OBJECTIVES

One of the things that has been wrong with curriculum planning and development in the past has been the fact that there was a lack of suitable guidelines or goals to be achieved by any particular curriculum development program. Over the past several years, this facet of education has been gaining increasing momentum, and we can turn our attention

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5. Ibid., p. 2.

to some of the research that has been done in this field. There have been several committees set up in almost every province or state in North America, entrusted with the task of coming up with definite aims and objectives which would, if followed, achieve desired results. Besides, individual and group efforts have come up also with numerous sets of guidelines regarding curriculum formulation. Whereas, all these committees as well as individual or group efforts have produced their own versions; a more careful look at their activities leads one to the same conclusion. It is the conviction of the author, that the dominance of the subject design of the curriculum must give way to more crucial and relevant aims of schools and society.

> "The turn-away-from-the-subjects efforts of the past have not been successful, and I can hope that a new proposal to this end now finds a more fertile ground in the conflicts and dissatisfactions of today. Certainly, review of the plans made and implemented today and yesterday leaves no doubt that the dominant assumption of the past curriculum planning has been the goal of subject matter mastery through a subject curriculum, almost inextricably tied to a closed school and a graded school ladder, to a marking system that rewards successful achievement of fixed content and penalizes unsuccessful achievement, to an instructional organization based on fixed classes in the subjects and a timetable for them. The subject design is the very core of the mantle, depending on the critic. Many of the same critics still assume continuation of the subject curriculum, although the assessors would have us individualize its learning, and the humanists would have it open to inquiry."[6]

The above paragraph almost summarizes the dilemma in which the curriculum designers find themselves today. Today's dissatisfactions

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6. Ibid., p. 3.

with a curriculum geared to the subjects point to the acceptance of some assumptions, different aims and objectives or different goals of schooling. The following are the ones which the author of this article has arrived at after consulting a number of recent publications by various committees as well as individual research efforts:

1. "The central purpose or objective of a good, sound curriculum should be to provide a planned program of learning opportunities to achieve broad educational goals and related specific objectives for an identifiable population served by a single school center. These planned program or programs are to be arranged within categories which can be described as curriculum domains."[7] According to Dr. William Alexander, there are four such domains - personal development, human relations, continued learning skills, and specialization. These curriculum domains also represent a classification of major educational goals and related learning opportunities that seem fairly universal. It is not assumed that each school center would necessarily have curriculum plans within each of these domains, nor that domains cannot or should not be developed. The essential idea is to have broader grouping of curriculum opportunities than in the traditional division of schooling into the disciplines and nondisciplines. Such a broader grouping gives the basis for more functional and vertical planning and wider involvement of the persons concerned. It also should ensure the wiser selection of subjects and subject content.

The term "educational goals" as mentioned above is a rather

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7. *Ibid.*, p. 10

broad one, and could in itself be a topic for a research paper. Within the short space available here, the author is stating below the five main objectives of secondary education as pointed out by the Core Committee on the Reorganization of the Secondary Schools, established by the Department of Education, Province of Manitoba:[8]

1. Development of Communication.
2. Personal and Social Development.
3. Development of Creativity.
4. Development of Analytical Thinking.
5. Skill Development.

2. "An eff ctive secondary school curriculum should contribute to the intellectual, social, vocational, and personal development of the student by striving to make provisions for the identification of:[9]

A. Those common and special skills that are so important that students be able to demonstrate an acceptable proficiency in them prior to graduation;

B. Those experiences and areas of man's culture and knowledge that are considered sufficiently essential that all students should be exposed to them; and

C. Those areas of specialization related to specific student interests, aptitudes, and abilities.

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8. The Secondary School, Report of the Core Committee on the Reorganization of the Secondary School, Department of Education, Province of Manitoba, 1973, p. 5-6.

9. Ibid., p. 18.

3. "One of the most basic goals of a good, sound curriculum should be to provide opportunities for deserving and earnest boys and girls who have not been able to succeed in the regular school program - to provide a worthwhile curriculum for students who may not be of clinical or special education type, yet who need special curriculum that will include basic saleable skills for future livelihood."[10]

4. A suitable curriculum should offer enough flexibility so that the individual learner is actively involved in planning his own curriculum, in an open process that eliminates the hidden curriculum. In 1957, a brochure on "One Hundred Years of Curriculum Improvement," published by The American Society for Curriculum Development, gave us the statement that:

> "More recently, the philosophy of democratic participation and the recognition of the dynamic nature of learning have led to emphasis upon teacher pupil learning. For the past 20 years schools have been experimenting with ways to improve the process by which children and young people help set the goals, plan the activities and evaluate the results of their work with the leadership of the teacher."[11]

5. A good curriculum should enable a learner progress along a series of curriculum continuums, each within a curriculum domain, rather than up an individual ladder. Harold Shane described a curriculum continuum as "an unbroken flow of experiences planned with and for the individual learner throughout his contacts with the school," and noted

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10. William M. Alexander, The Changing High School Curriculum, Readings; Holt, Rinehart & Winston, Inc., 1972.

11. Prudence Bostwick, Chairman, One Hundred Years of Curriculum Improvement, 1857-1957, (Washington, D. C., ASCD) p. 7.

that "implementation of this concept would eliminate such features of the present school as failure, double promotion, special education, remedial work, dropouts, compensatory education, report cards and marks."[12]

These five aims and objectives of a good and sound program of curriculum development are broad enough so that practically each and every aspect of satisfactory system of high school education can be accommodated and realized.

MODERN TRENDS IN CURRICULUM DEVELOPMENT PATTERNS

Enough has been said above about the importance of curriculum in a modern high school, and the goals such a curriculum should meet to provide quality education for all students, taking into account their abilities, aptitudes, needs and aspirations.

> " Traditions which have bound secondary schools to set patterns are being broken. Secondary school education is on the verge of a revolution which holds much hope and some apprehension. Schools are becoming more comprehensive as they provide for the once forgotten dropout, and yet more homogeneous in student population as they specialize in serving the increasingly stratified, urbanized, neighborhood population clusters of inner city and the suburbs."[13]

> "All this has led to concerted efforts on the part of administrators, curriculum planners, teachers and other groups associated with education. The innovations in curriculum development, scheduling, and school organization are all the results of such concerted efforts. The results has been a flood of innovative curriculum development projects, whose

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12. Harold Shane, A Curriculum Continuum: Possible Trends in the 70's, Phi Delta Kappan, (51:389-392, March, 1970).

13. Association for Supervision and Curriculum Development, National Education Association, Humanizing the Secondary School, Washington, D. C., 1969, p. 1.

sole purpose has been to set worthy educational goals, to look at students as individuals, and to examine alternative approaches to curriculum and instruction. Such efforts include and introduce a cycle of self-renewing activity which, if insightfully followed, can make schools exciting places in which to be, both for teachers and students.

Never have secondary schools had a better opportunity for self-examinations and decisive action. Never before have they had such massive forces exerting pressure on them nor have they had so many alternatives to choose from as they chart their future courses. The schools can now decide whether they are to be more humane, more sensitive to student needs, and more able to serve the individual; or they can become more rigid and inflexible so that only the conforming students will pass through, while others will escape to be discivered by the job corps, free universities, or other institutions yet to be established.

There is hardly any way to avoid making changes for a future which demands constant redirection all the time. And changes there have been, may be too many of them, so that looking from the point of view of an average high school teacher, it has become an uphill task, having to shoulder the burden of having to decide which approach to follow and when. For, in spite of all the innovations in curriculum development patterns, the teacher remains the master of the instructional situation, despite such innovations as team teaching, instructional television, computer scheduling, paraprofessional assistance, programmed materials, and now the products of large curriculum ventures. The sum of teacher's professional knowledge, skill, committment, insight, experience, values, attitudes, fears, aspirations and other deeply personal characteristics makes up a "gestalt" which structures and permeates the instructional event."[14]

Over the past several decades, the last two in particular, the

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14. William M. Alexander, The Changing High School Curriculum, Readings; Holt, Rinehart & Winston, Inc., 1972, p. 18.

various curriculum development patterns which have evolved, can be classified as follows:

1. The Subject Centered Approach, which is by far the oldest and is commonly referred to as the traditional approach to curriculum construction. It is content-centered, the basic learning activities of all students are selected from and organized into courses of study, such as science, maths, social studies, music, arts, etc.

2. The Humanistic Approach, almost all the major innovations in curriculum development patterns over the past two decades or so have been directed at making the curriculum more humane. Research abounds in the humanistic approach to curriculum, which is primarily aimed at making schools more humane. Since this approach to curriculum development is the most promising of all, the author wishes to discuss it in a little more detail.

> "Developing a humanistic curriculum means answering a whole lot of questions:
>
> 1. What is to be taught and how?
> 2. How are the schools to be organized?
> 3. How is the student performance to be evaluated and for what purposes?
> 4. What is meant by a humane school?
>
> Although no one type of curriculum can be suitable for one province as a whole, leave aside the country, yet the humanistic approach to curriculum development seems to be the most promising of all.
>
> The main criteria towards humanizing the curriculum is to break down subject matter lines so as to liberate the mind even further and free the individual learner from traditional subject matter bodies of knowledge, and to provide him with skills to explore ideas, to seek information, to generalize from it and to project these genralizations towards new and

and better ways of living."[15]

The curriculum in any formal setting will be infused throughout with knowledge. It is important, therefore, that one clearly grasps the humanistic tradition about the nature of knowledge in order to deal intelligently with curriculum design. Jerome S. Bruner, who advocates this approach, places emphasis on motivation secured through the subject and successes in learning over a long period of time as opposed to temporary motivation secured through immediate interests and instructional media. The process of learning does motivate further learning. However, some initial motivation is often necessary."[16]

> "There are far more principles, relationships, and knowledge in any subject than can be included in any secondary school course of study; thus, a selection must be made. If the selection is based on essential aspects of structure and the interests and concerns of pupils, then subject content will not be neglected, and initial as well as subsequent motivation will be secured. This results in a humanistic approach which combines the structure of academic subjects and the needs, abilities, concerns, and interests of pupils. These factors can be employed in the selection of the content, in motivation, and in helping pupils make wise choices in electivies. After a student has embarked upon a course of study, the structure of the discipline, as well as the student's own interests and needs, will determine the content."[17]

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15. Association for Supervision and Curriculum Development, National Education Association, Humanizing the Secondary School, Washington, D. C., 1969, p. 43.

16. Jerome S. Bruner, The Process of Education, N. Y., Vintage Books, Random House, pp. 1-32.

17. John I. Goddard, Direction and Redirection for Curriculum Change, ASCD Newsletter Exchange, Vol. 8, No. 3, April 1966, p. 2.

The author of this paper strongly supports the view as expressed by Dr. John I. Goddard. (see footnote number 17)

A curriculum design for a humanistic school should be focussed directly upon the creation of conditions for fostering the development of human beings.

In the publication, "Humanizing the Secondary School," published by the Association for Supervision and Curriculum Development, N.E.A., the following characteristics are offered regarding a humane secondary school curriculum.[18]

> "Basic Concept: A humane secondary school is one that provides a broad and comprehensive curriculum in which ample opportunities exist for the optimum exploration and development at the adolescent level of talents and capabilities of all youth of the community, and one in which teaching and instruction are primarily designed to foster such development.
>
> 1. Such a school offers ample courses at appropriate levels of depth and sophistication to enable each student to develop his own talents and potentialities.
>
> 2. Offerings are available in each of the fields appropriate for study at the secondary level.
>
> 3. Advanced courses are offered in each area of study so that the most talented students in that area are served.
>
> 4. A broad variety of programs for specialization are offered so that pupils may elect programs and courses on the basis of post secondary career plans or of personal significance to them.
>
> 5. A variety of class sections as to content, methods of instructions, level of scholarship, and expectations set for pupils are available in required

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18. Association for Supervision and Curriculum Development, National Education Association, Humanizing the Secondary School, Washington, D. C., 1969, pp. 121-127.

areas of study.

6. Appropriate interdisciplinary and inter-area types of programs are offered, particularly seminar-type discussion groups on significant issues and problems in group and personal living.

7. The staff continuously appraises and evaluates its offerings and the contents and instructional methods used, and reconstructs the curriculum to take account of new forces, new knowledge, and new conditions as is seemed desirable.

8. Ample opportunities exist for adolescents individually to study and engage in other types of learning activities such as research, creation, experimentation, construction, and design."

In the book, "The Changing High School Curriculum" - Selected Readings, by William Alexander, Dwight Allen discusses a "A Technology and Performance Curriculum," in which he outlines the role of technology in humanizing the secondary school curriculum.[19]

> "If we can direct the role of technology in education and if we can match the performance of our students with the needs of society, we can spend less time, paradoxically, on power and more on potential; less time on consumption and more on education; less on learning and more on being human."

To this end, he suggests the following alternatives:

Specific uses of technology in -

1. Scheduling to provide teachers and students with a greater range of alternatives for educational decision making;

2. Individualizing instruction by providing appropriate content, opportunities for learning experiences, resource laboratories,

and [illegible]

19. William M. Alexander, <u>The Changing High School Curriculum</u>, Readings; Holt, Rinehart & Winston, Inc., 1972, p. 426.

and teacher pupil interaction;

3. Rethinking and redefining the role of teachers by recognizing different levels of performance and differentiating the responsibilities of teaching;

4. Establishing performance criteria as a basis for developing more identified measurement tools for student achievement of the broad instructional objectives of the school.

Dr. Dwight Allen concludes his paper on "Technology and Performance Curriculum" by saying that "unless secondary schools meet the challenge posed by the curricula based on performance and not just innovation, the danger is that such schools will cease to serve adequately the society whose future citizens it is their responsibility to educate."

To summarize, in looking at the various curriculum development patterns discussed above, it is clear to the author of this paper that out of all, the humane type of curriculum emerges to be the most promising for the present as well as for quite some time to come. So, "towards a humanistic curriculum" seems to be the slogan as one reflects upon the changes through which curriculum design patterns have undergone, and peeps through the future.

In his book, "Towards a Humanistic Curriculum," Dr. Duane Manning offers us this assessment of his views about humanistic schools as they are eventually conceived.[20]

> "Man stands poised upon the planet earth preparing for one of the greatest adventures - moving out into space to explore his galaxy. He looks at the

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20. Duane Manning, Toward a Humanistic Curriculum, Harper & Row, New York, 1971, p. 299.

> stars and knows that it is possible for him to reach out and go where no man has ever gone before. And he will surely find other life forms, some of which are more highly developed than him, and some that are not as far along the way. ....Along with his preparations for this great adventure, he must make corresponding efforts for an even more splendid achievement - that of improving the quality of his own existence. He must restore the purity of his environment, and he must work in such harmony with nature that she can continue the miracle of life. He must deal more understandingly, effectively, and lovingly with all men and somehow conquer war, poverty, human bondage, and other destructive forces. If he can more nearly achieve the basic virtues of truth, justice, wisdom, and love, then he can move out among the stars with the pride and confidence of taking into the galaxy a positive life force.
>
> Can he do such things? Perhaps, but one should not underestimate the enormity of the task. The hour is later than he knew and the difficulties compound even as he now shows a belated recognition of his peril. An ecological disaster draws ever nearer, and the distorted furies from accumulated brutalizations of the human spirit smoulder throughout the land. Difficult though it may be to contemplate, man would not be the first major species to become extenct - only the first to fashion his own destruction. There is still hope that all that is most treasured in life and human values can survive if men accord them their rightful priority and mount their best efforts to that end. And if this deepening crisis is successfully resolved, humanistic schools as they are eventually conceived will play a significant role in the achievement."

CURRICULUM DEVELOPMENT PATTERNS - IN RELATION TO PHYSICS

There have been many changes in the science curriculum in recent years. Numerous groups, organizations, and scholars have worked to improve the content of the science courses in all levels of the public schools. The main concerns have been to change the approach and to improve the content. Prior to these innovations, much attention and emphasis were placed on functional knowledge. Emphasis was placed on understanding common every day phenomena such as how machines work, how electricity makes light, how an airplane flies, and other such applications of knowledge.

> "Scholars are now of the opinion that such a curriculum did not provide systematic content in a logical organization nor did it give the reader or the student any real feeling for the procedures employed by the discipline. They also argued that providing students with practical scientific knowledge was to lead them down a corridor to a blind end since technology changes constantly. They maintained that as our information about the universe changes, so does the scientific theory. Therefore, the best preparation would be the kind which is based on systematic content or the structure of the subject matter. And of course, scientists argue that the content of science and the methods of science are inseparable."[21]

To this date, science has been structured in a way which is most well known to most science teachers. This method is that of dividing science into very large categories such as physics, chemistry, biology and earth science. Most of the curriculum development projects so far have been in single disciplines. PSSC, Chem Study, BSCS are some examples. Some more recent projects are trying general approaches to families of disciplines. Examples are AAAS, SCIS, and COPES. A new curriculum project at the Hawaii Curriculum Center takes "a pluralistic view of sciences."

The fantastic rate at which scientific knowledge is piling up has prompted curriculum makers to shift instructional strategies. Hence, new project materials have emphasized: (a) depth of experience in a few

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21. Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc., Boston, 1973, p. 376.

topics in contrast to broad converage; (b) concepts and generalizations rather than memory; and (c) inquiry rather than the accumulation of the "rhetoric of conclusions."

This curriculum project movement has a number of implications for teachers. Teacher roles are becoming more precisely defined, requiring, for example, a "physics teacher with background in PSSC" rather than a science teacher who can do physics.

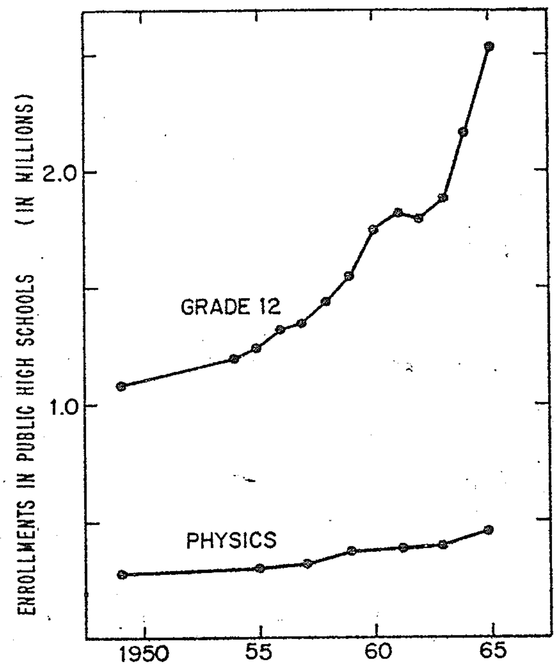
DEVELOPMENTS IN PHYSICS CURRICULA - TRENDS AND PATTERNS

The choice of electives in most high schools is usually limited to three as far as sciences go; physics, chemistry and biology. Some high schools offer courses in advanced general science, physical science, earth-space science, and national curriculum projects in biology, chemistry and physics.

As the figures and charts given on the next page show, the enrollment in biology was the largest, followed by chemistry and last of all, physics. In the United States, for example, each year over 2.5 million students are enrolled in the twelfth grade of public schools. Of these, some two million would have avoided physics. Since we are primarily concerned about physics enrollments, the graph in Figure 1 on page 24 shows the number of students taking physics versus the total number of students enrolled in the high schools. Figure 2 shows almost steady rate of decline in nationwide percentage enrollment in physics. This declining trend in physics enrollments has been causing concern to all those who realize and know the increasing importance of physics in our society. This was made abundantly clear in the first chapter.

ENROLLMENT TRENDS IN PHYSICS AS COMPARED TO OTHER SCIENCES

Figure I



A comparison of trends in physics enrollment with numbers of pupils in twelfth grade in public schools. The source of these figures is the *Digest of Educational Statistics* (1965 ed.). 1964 figures from National Center for Educational Statistics, USOE.

Figure 2

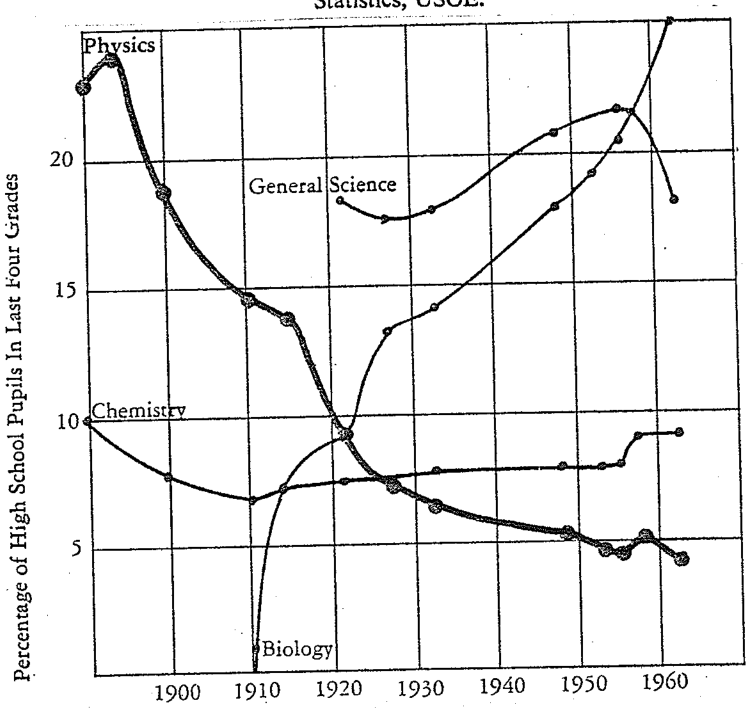
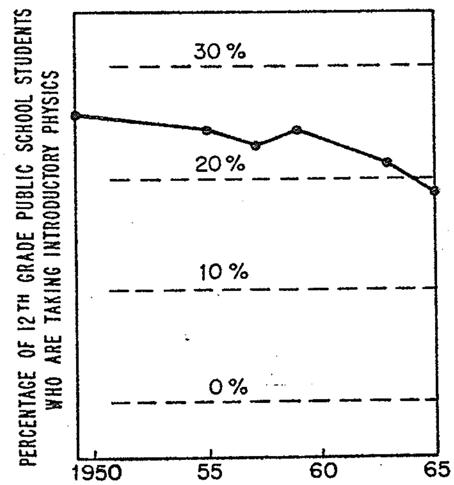
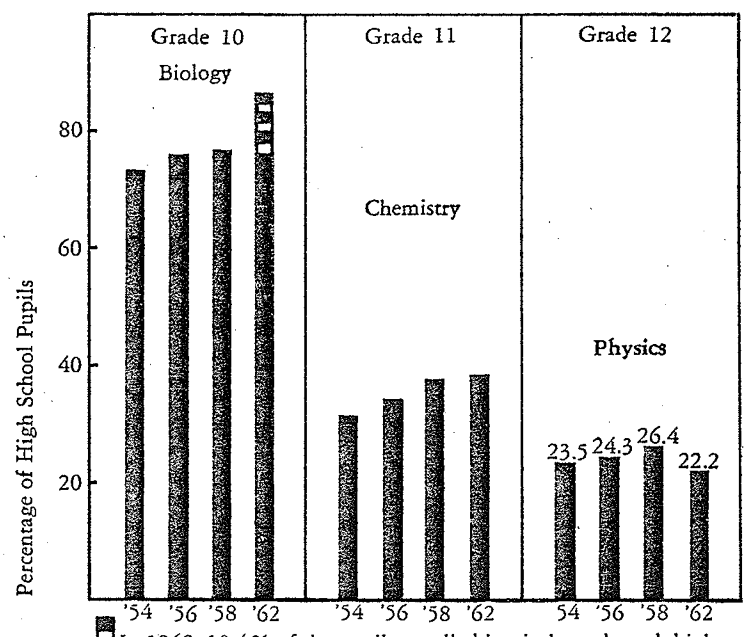


Figure 3



An almost steady rate of decline in nationwide percentage enrollment in physics.

Figure 4



In 1962, 10.4% of the pupils enrolled in ninth grade took biology

Survey was not conducted in 1960

> "Physics is a science through which young adults can begin to consider some basic questions about how we can attempt to explain the phenomena we observe. Also, throughout its long history, physics has had profound effects on the philosophical orientation of Western culture. The individuals, instruments, assumptions, and expanding theories of physics provide an almost ideal vehicle through which young people can inspect science in the making, and engage to some extent in the same process. When applied to political affairs, physics has been one of the major contributors to our advancing technology. For these and other reasons, we are pursuaded that physics should be studied by far more high school students."[22]

The first major curriculum development project in physics was undertaken by the Physical Science Study Committee, which was founded at the M.I.T. in 1956, to develop an improved introductory course in physics. The project was sponsored by the National Science Foundation as well as the Ford and Sloan Foundations. The materials produced by the committee were tried, evaluated and revised for three years before they were released for general use in the fall of 1960. The following table shows the growth in the use of PSSC materials between 1957-67. (Recent enrollments are not available).

Table I: Use of PSSC Materials

(From PSSC Newsletter - 1966)

Year	Number of Teachers	Number of Students
1957-58	8	300
1958-59	270	11,000
1959-60	560	22,500
1960-61	1,100	44,000
1961-62	1,800	75,000
1962-63	3,000	125,000

22. The Physics Teacher, May 1967, p. 213.

Year	Number of Teachers	Number of Students
1963-64	4,000	160,000
1964-65	5,000	200,000
1965-66	5,500	225,000
1966-67	6,000	250,000

It is interesting to note here, that although the physics enrollment did continue to increase, as the above table shows, the percentage of students taking physics kept on declining, as shown in Figure 3, page 25. What this means is that PSSC did not help arrest the declining trend in physics enrollments.

In the words of Dr. Gerald Holten, Professor of physics at Harvard University, and one of the co-directors of Harvard Project Physics,

> "PSSC was primarily developed by research scientists who rightfully believed that a change was needed. When writing the materials, the PSSC Committee and others neglected to take into account the wide diversity of students' abilities in a classroom. Unknowingly, they catered to the above average student, while thinking they were developing a curriculum for the average student who took physics. Future committees can capitalize on the experience of the 1960's to develop courses which are needed for all levels of pupil abilities."[23]

The second edition of the PSSC textbook, Physics, was published in 1965 by D. C. Heath and Company. The following statements taken from the preface of the book tell how the unifying principles of physics are presented:

> "The PSSC course consists of four closely interconnected parts. Part I is a general introduction to the fundamental physical notions of time, space and matter: how we grasp and how we

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23. Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc., Boston, 1973, p. 114.

> measure them. As the student learns of the almost boundless range of dimensions from the immensely large to the infinitesimally small, from microseconds to billions of years, he finds out how these magnitudes can be measured. He learns that instruments serve as extensions of his senses. Laboratory experience shows how we first measure by direct counting and then extend our range of measurements by calibrating and using simple instruments such as stroboscopes and range-finders.
>
> Part II deals with the principles of optics and leads the students to the development of the particle and wave model of light. Part III and IV deal with the principles of mechanics, electricity and magnetism and modern physics".

According to Arons,[24] the PSSC course is associated with a significant improvement in the ability of the student to learn from laboratory work in a college physics course. Verbugge[25] compared matched groups of former PSSC pupils with former conventional high school physics students. The study showed that PSSC students obtain a higher percentage of A or B grades and about the same number of middle grades. This would seem to indicate that the PSSC course at least does not hinder the student who goes on to college. It does not necessarily mean that it prepares him either, even though many PSSC students indicate that PSSC was an extremely valuable course and did prepare them for college work.[26]

What it means then is that the PSSC course is mostly a college

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24. Ibid., p. 113.

25. Ibid.

26. Ibid.

preparatory course. The author's own experience of teaching this course over the last six years convinces him that this is actually the case. PSSC course presents physics as seen by a physicist. It fails to take into account the historical, cultural, and social or even environmental aspects of the subject. As it turns out, the course has little or no relevance for a student who wants to study physics as a terminal subject and needs to study it for getting into one of the vocational courses later on. Even many university oriented students wishing to major in physics and other related subjects such as engineering, find the level of the course too hard. The main reasons cited are that there is too much emphasis upon mathematical work, and the book itself is hard to read through.

There are those who say that PSSC has contributed to the relative unpopularity of physics. What is needed, then, is a different type of a course, which would get over some of the difficulties experienced with the PSSC course. There was one thing the PSSC course started; it was the need to have a careful look at what was being taught and the way it was being taught. As far as that is concerned, the PSSC course started a trend which caught on, and later gave rise to other major curriculum development efforts being set up in almost every other branch of science.

> "What is needed is to revitalize the subject of physics. The college preparatory function of high school physics continues to dominate the thinking of physics teachers. Physics as a c college entrance requirement has been so firmly entrenched that teachers have had little opportunity to do more than follow a rather definite course of study based on factual information and laws which college professors deemed necessary as a basis for achievement in college.

> Physics teachers must discard the artificial standards established by colleges and universities and make physics a vital and exciting subject."[27]

A NEW PHYSICS CURRICULUM DEVELOPMENT PROJECT - HARVARD PHYSICS PROJECT

Harvard Project Physics (HPP) is an outgrowth of the efforts of about eighty physicists and teachers to produce a one year course in physics for use in high schools. In addition to physicists and high school teachers, the advisory committee set up for this course had chemists, historians of science, philosophers of science, science educators, and experts interested in publishing and in scientific manpower problems. This is symbolic of the decision of the developers of this course to draw from a great variety of fields and competences. From the very outset, the course was built on the broadest possible base. For instance, the unique arrangement of having three co-directors for the course is significant: Professor Watson of the Harvard Graduate School of Education is a science educator who has also done professional work as an astronomer; Dr. James Rutherford of the faculty of the Harvard Graduate School of Education is a former high school teacher and a superb administrator, ever sensitive to the day-to-day needs and possibilities of the classroom, and Dr. Gerald Holten is a physicist who is also working in the history of physical science, particularly physics.

In 1962, a feasibility study supported by the Carneige Foundation was conducted. In 1964, work on the project was started on a larger scale supported by the Carneige Foundation, U. S. Office of Education,

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27. Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc., Boston, 1973, p. 110.

Sloan Foundation, and the National Science Foundation.

A pilot version of the course for study was used in 1967 by 2,600 students on a controlled experimental basis[28] in more than fifty schools in the United States. The course was adopted in 400 schools involving 5,000 students in 1969-70.[29]

The course is for a wide range of pupil abilities. It is intended to attract and be suitable for a great majority of students in high school and is designed for an average student. Physics is presented in a "broad humanistic context to try to show connection between it and man's other intellectual and artistic as well as social activities.[30] Independent study, programmed instruction, laboratory activities and investigations, lectures and seminars are some of the methods of instruction which are used in the course. A major innovation in the laboratory part of the course is a wide use of film-loops, which adds a completely different touch to carrying out laboratory work and makes it much more interesting and easier.

Present in Figure 5, page 32, are the different components (media) making up a typical unit (Unit I - Concepts of Motion).

AIMS AND OBJECTIVES OF HPP (now referred to as PROJECT PHYSICS)

Dr. Gerald Holten, one of the co-directors of this course outlines

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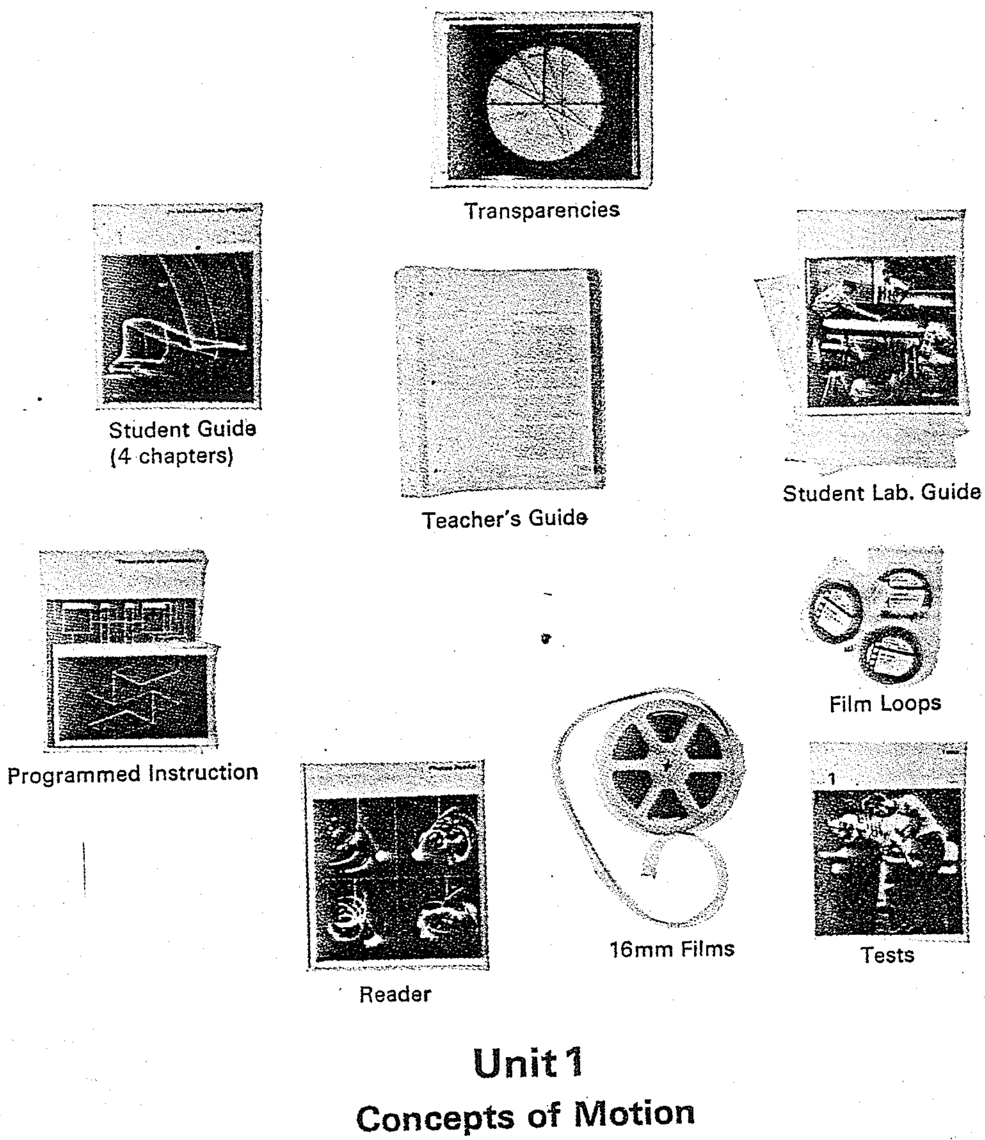
28. Gerald Holton, The Physics Teacher, May 1967, and Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc. Boston, 1973, p. 113.

29. Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc., Boston, 1973, p. 114.

30. Ibid., p. 114.

Figure 5

DIFFERENT COMPONENTS (media) MAKING UP A TYPICAL UNIT



Different components (media) making up a typical unit (Unit 1–*Concepts of Motion*).

the four main objectives of this course as follows."[31]

1. First, we wish to create a coherent, tested course for use on a national scale alongside the others that have been developed previously; but it is to be a course that accentuates those aspects of physics and pedagogy which have so far not been prominently incorporated into course developments in physics on the high school level, although they are widely held to be desirable. We can hope, in this way, to provide variety of choice in the physics teacher's arsenal.

2. We hope to stem the decline in proportionate enrollment in physics at the high school level - a decline which in fact is now reaching into college years. This according to Professor Watson (figures regarding declining physics enrollments cited previously on page 25) is a deeply troublesome situation, one which is nothing less than a national emergency.

3. An obvious and necessary decision to provide teachers with all the necessary aids for teaching good physics in realistic classroom situations as they now exist - a single one year course in senior high school. Here we define good physics in the widest, most humanistic way possible, rather than in professional terms alone.

4. Our course development requires thinking entirely afresh through some basic questions, such as the new role of the teacher and his involvement with the class, the new desire to allow greater diversity and flexibility, and the new opportunities opened up by the developing technology of education. Therefore, we have been developing new guide-

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31. The Physics Teacher, May 1967.

lines that may help curriculum development in general in this country.

GUIDELINES AND ASSUMPTIONS UNDERLYING PROJECT PHYSICS COURSE

In the spring issue of 1968, Newsletter Number 7, the three co-directors of the course outlined the following eight points that, according to them, form an integral part of their approach to the PP course.

1. Physics is for everyone.
2. A coherent selection within physics is possible.
3. Doing physics goes beyond physics.
4. Individual persons need flexible course.
5. A multimedia system stimulates better learning.
6. "The time has come to teach science as one of the humanities".

This assumption has been supported by a number of different authorities. The Physics Teacher, March 1965, agreed that a physics course with a cultural component is needed by everyone. The Nobel Prize physicist, Dr. I. I. Rabi has eloquently spoken for the view that physics now lies at the "core of the humanistic education of our time", and he added, "science should be taught at whatever level, from the lowest to the highest, in the humanistic way. By which I mean it should be taught with a certain historical understanding, with a social understanding and a human understanding, in the sense of the biography, the nature of the people who made this construction, the triumphs, and trials, the tribulations". Similarly, Dr. Donald F. Hornig, the President's science advisor, has recently said, "The time has come to teach science as one of the humanities".

Also, in March 1965, the Physics Teacher, a survey reported the replies of 1380 high school physics teachers. Of them, 79 percent thought that high school students stay away from physics because in their schools the courses as now given do not suit their abilities and desires; 91 percent said also that a physics course with a cultural component is nearly needed by everyone."[32]

7. A physics course should be rewarding to take.

8. A physics course should be rewarding to teach.

These eight guidelines and assumptions have been discussed at length in the above mentioned newsletter.

ROLE OF THE PHYSICS TEACHER IN THE PROJECT PHYSICS COURSE

Again, in the words of Dr. Gerald Holton, "We have begun to respect the role of the teacher as collaborator in making curriculum development work in the classroom on his own terms, and we have become more interested in considering the different needs of different students in the same classrooms... We have different assumptions of what is and is not feasible or desirable for schools to do: For example, we would not today develop a curriculum that caters only to the intellectual elite."

A BASIC COURSE WITH KEYED OPTIONS - SUPPLEMENTARY AND COMPLEMENTARY MATERIALS (HPP Newsletter Number 3, Spring 1966)

Departing from the traditional pattern of a more or less monolithic course package of fixed size, PP has developed a course consisting of two parts; one is a relatively short, or at least manageable, basic course, consisting of the six units of the basic text, the associated laboratory and demonstrations, audio-visual materials (films, film-loops, film strips, and transparency overlays), programmed instruction, examin-

32. The Physics Teacher, May 1967.

ations and teacher guides. This basic course defines the minimum dimensions of activity for the school year. In addition, PP has also produced and is still producing a large array of supplementary and complementary materials of all kinds, designed to be used in coordination with the basic course materials. With the aid of a Teacher Guide, the teacher can make selections from these optional materials to make the complete course.

An introductory course cannot cover all topics in physics. Through trial versions and long discussions only the basic course materials are contained in the six text units. Other topics are available for use in the form of optional materials. The options will be exercised by the teacher according to his individual training and preference, his own developing ideas, and his students' abilities and interests. The basic course has a complete structure and form of its own, however, and may well be the form in which the average teacher in an average class prefers to begin teaching the course.

The two stage system is intended to help in dealing with the wide spectrum of our intended audience - students ranging from the bright prescientist to the potential drop-out - and with the variety of teachers in a wide range of academic situations. Every student should be able to handle the basic course and then the majority of classes will still have from one to three months of school time remaining after the completion of the basic part of the course, depending on the extent to which the teacher uses the optional materials during the course and on the pace maintained by the class as a whole. Consequently, there is a large amount of flexibility to afford latitude for individual students, teachers, and school systems. In addition, the course has tried to assure rapid building of confidence on the part of the teacher by avoiding unnecessary innovations; it would not be realistic to demand that the general structure of the subject matter be radically removed from what teachers have been trained to handle.

If a teacher wishes to expand on a given topic in the basic course, he may select an article, reprint, or essay from the Reader, a special chapter, or a supplementary unit. As long as the basic course is made accessible to all students, it is left to the discretion of the teacher whether one or more additional selections are assigned for study by the entire class, whether different selections are assigned to individual students, or whether any additional selections specifically prepared by PP are assigned at all.

Each of the six, separately bound units of the basic text has its own conceptual structure which holds its four chapters together as an integral unit. (These six units are now also available as a single textbook) Each unit makes some connection to its neighbour by means of its prologue or epilogue, one outlining the important considerations that will be encountered in the chapters ahead, the other leading into the next unit while consolidating the work just studied. Given on the next page is a general table of contents for final version of the basic text units. Bought separately, the handbook or the lab-guide is included at the end of each unit. Otherwise, the text and the lab-guide (called handbook) are also available separately, each containing all the six units bound into a single book.

THE PROJECT PHYSICS UNIT OUTLINE

UNIT I. Concepts of Motion:

How do things move? Why do things move? The principal tasks are: (1) to lead students to answer these questions; (2) provide insight into the way scientists go about doing their work.

Chapter 1. The Lanuage of Motion

Chapter 2. Free Fall, Galelio Describes Motion

Chapter 3. The Birth of Dynamics - Newton Explains Motion

Chapter 4. Understanding Motion - A Trip to the Moon

UNIT II. Motion in the Heavens:

Account of how men have attempted to explain the motions of heavenly bodies.

Chapter 5. Where is the Earth? - The Greeks' Answer

Chapter 6. Does the Earth Move? - The Work of Copernicus and Tycho

Chapter 7. A New Universe Appears - The Work of Kepler and Galelio

Chapter 8. The Unity of Earth and Sky - The Work of Newton

UNIT III. The Triumph of Mechanics:

Focusses on the generalizations of Newtonian mechanics by means of conservation laws for mass, momentum and energy and on the application of Newtonian mechanics to collisions of objects, heat, and waves.

Chapter 9. Conservation of Mass and Momentum

Chapter 10. Energy

Chapter 11. The Kinetic Theory of Gases

Chapter 12. Waves

UNIT IV. Light and Electromagnetism:

Helps students reach an understanding of electromagnetic waves.

Chapter 13. Light

Chapter 14. Electric and Magnetic Fields

Chapter 15. Faraday and Electric Age

Chapter 16. Electromagnetic Radiation

UNIT V. Models of the Atom:

To develop Atomic theory, emphasis on the interplay of evidence of conceptual models.

Chapter 17. The Chemical Basis of the Atomic Theory

Chapter 18. Electrons and Quanta

Chapter 19. The Rutherford - Bohr Model of the Atom

Chapter 20. Some Ideas from Modern Physical Theories

UNIT VI. The Nucleus:

Investigations of the discoveries made which led to the study of the nucleus itself.

Chapter 21. Radioactivity

Chapter 22. Isotopes

Chapter 23. Probing the Nucleus

Chapter 24. Nuclear Energy and Nuclear Forces

PSSC VERSUS PP

According to Dr. Holton, Project Physics is in no way to be thought of as an alternative or rival to PSSC. We shall need both of these, and many other good courses, to meet the needs of variety and volume of physics classes.

EVALUATION OF THE PROJECT PHYSICS COURSE

> "The evaluation of the course was handled by a special team, specializing in this branch of education. Evaluation of the PP materials has been extensive. A book-length report of the evaluation: "A Case History in Curriculum Evaluation: HPP", gives many of the details of the evaluation studies. One study shows that on the Physics Achievement Test of the College Entrance Board, the PP students on the average performed as well as students who had been exposed to other physics courses. A test measuring student satisfactions was administered to PP students as well as to students in other physics courses. The PP students agreed with statements like:"[33]
>
> 1. "I think this physics course is designed in such a way that even those who have little background in mathematics can gain much from the course."
>
> 2. "I think learning about men and women who made physics grow helped to make the course more interesting."
>
> 3. "I hope they don't change the course too much."

PP students were less likely to agree with statements like: [34]

> 1. "Physics is one of the most difficult courses I have taken in high school."
>
> 2. "No matter how you look at it, physics has to be a difficult course."

It was also significant to note that achievement gains of girls was greater than boys on the PP course. This suggests that the course has a wider appeal than a traditional physics course.

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33. Alfred T. Collette, Science Teaching in the Secondary School, Allyn & Bacon, Inc., Boston, 1973, p. 116.

34. Ibid.

Another study involved students who would not normally take physics. A total of 194 students were invited to take the PP course. The following summarizes the results reported: The students had significantly lower scores on academic activities, on a physics achievement pretest, on interest in physics, and on I.Q. than regular PP students. The average I.Q. of the students recruited was 108 while the average of the regular PP group was 116. Even though the invited group started lower and at the end of the course also finished lower on almost all tests, they should at least achieve the same or in some cases better greater gains compared with regular students on most tests. Gains in scores on tests measuring achievement, attitude to science, interest in physics, and satisfaction with the course were about the same for both groups. About 51% of the regular students achieved A or B for the first physics grade and 46% of the recruits received A or B. About 73% of the invited group and 60% of the regular PP students said they would recommend the course to their friends.

OTHER COMPONENTS OF THE COURSE

A. TEACHER BRIEFING FILMS - TITLES

> "The PP encourages each teacher to adapt the course materials to his own classroom situation. Since many teachers are pressed for time, the developers of the course have prepared a number of Teacher Briefing Films which can be borrowed or rented from the publishers of the final version of the course materials, M./S. Holt, Rinehart & Winston, Inc. The following is a partial list of such briefings:"[35]

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35. Harvard Project Physics Newsletter Number 8, 1968-69, p. 11.

1. Polaroid Land Photography, I and II
2. Using the Oscilloscope
3. Orbit Plotting
4. Informal Class Activities
5. Waves
6. Waves, Mudulation and Communication
7. Film Loop Techniques, Parts I and II
8. Experiments With Microwaves
9. Measurement of Elementary Charge
10. Electron Beam Tube
11. Setting up the Current Balance
12. Working With the Current Balance
13. Photo-electric Effect
14. Half-life Experiments
15. Naked Eye Astronomy
16. Teaching About Physics and Society.

B. <u>SUPPLEMENTARY UNITS</u>

About twenty supplementary units are planned for use as an optional component of the course. Some of these have already been commissioned. Following are some of the titles:

1. Accelerators and Reactors
2. Special Relativity
3. Thermal Motion
4. Particle Physics
5. Physics As Seen From the Air
6. The Physics of Music

7. Physics and Sports
8. Science and Literatures
9. Physics For the Airplane Passenger
10. The Physics of Transportation
11. The Physics of Everyday Optics
12. Chemistry and Physics
13. Biophysics
14. Astronautics and Space Physics
15. Physics and Engineering
16. Social Consequences of Scientific Technology

More are planned.

SUMMARIZING THE VARIOUS COMPONENTS OF THE PP COURSE

To conclude, the following are the components of this multimedia course in physics:

The entire course is divided into six units, the titles of which have been described earlier. Each of these units consist of the following components:

1. Student text or student guide containing four chapters.
2. Student laboratory guide, called the handbook, contained at the end of the textbook.
3. Reader.
4. Programmed instruction.
5. Teacher's guide.
6. Film loops.
7. 16 mm films.
8. Tests.

9. Transparencies.

In addition to these, there are, as already mentioned, the teacher briefing films and the supplementary units.

SUMMARY

The author has traced the curriculum development patterns, starting from the beginning, including the definitions, aims and objectives, and the different approaches to curriculum design and development.

These were then discussed in relation to physics, wherein the two main curriculum development projects were explored in greater depth as to their goals and objectives, and their pros and cons discussed. It was pointed out that whereas the PSSC seems to be mainly designed for the elite, the PP course is a more humane course, much better suited to the needs of average students.

The author, however, likes to offer some criticisms and comments regarding these two major courses. As Dr. Holton of the PP course has said, the PP course is not a substitute for the PSSC course, and we need both of these courses at the same time. In an average high school of today, the percentage of college or university bound students is very small and continues to decline every year. Evenually, only 1 percent of the students graduating from the universities have studied physics. It is obvious, therefore, that something has to be done to arrest this disturbing situation.

There are points for and against both of these courses. It is true that whereas the PSSC course would not serve a substantial percentage of students, not to think of arresting the declining trends in physics enrollments, it is still a very good course for those going to major in physics at the college or university level, or those going into related fields such as engineering. But for a vast majority of students, the PP course would suit a great deal better and also, in author's view help arrest the downward trend in physics enrollments.

There are, however, a few points about which the author likes to disagree regarding the Project Physics course in its present form. The author offers these comments and criticisms as a direct result of his involvement with this course, first as a trainee in a PP summer institute, then as an instructor on the staff of such an institute in the United States for three consecutive summers, and now, for the current year, as a teacher teaching this course in his own high school on a pilot basis.

1. The project physics course was designed, according to its co-directors, as a one year course. Here in this province, physics is offered over a two year period. The author's own experience of teaching this course tells him that it is just impossible to teach more than two out of the six units over a one year period, so that not more than four units can be taught over a two year period. The selection of these units can be left at the discretion of the individual teacher.

2. Criticisms have been levelled against this course regarding the fact that this course is too easy. Taking this into account and also the criticism levelled against the PSSC course being too difficult, it is the opinion of the author that it is possible to arrive at a marriage between these two major courses and come up with a course that would meet both these criticisms and serve the needs of the students better, at the same time making physics more interesting and palatable. The author has tried this approach in his school both at the grade eleven and twelve

levels, and approximately 95 percent of the students think this is a much better course. The dropout rate has been cut to roughly one-third and the failure rate has been almost eliminated with the introduction of an individualized approach to the teaching of physics and following this newly developed course by the author. This would be discussed in greater depth in the next chapter.

3. Criticisms have also been levelled against the PP course regarding its content - too much emphasis at certain points and too little at others. Some areas of concern are a complete neglect of the physics of measurement, very little emphasis devoted to light and the development of the two models of light, complete neglect of sound and heat, and certain other areas.

4. The author proposes that the plan he is following in his school is a good one and meets the objections raised above, besides offering variety and choice and at the same time individualizing instruction, by following the "GRADE OPTION PLAN." Details of such a plan and all that has been said above shall be discussed in Chapter 4.

CHAPTER 3

THE PILOT STUDY

INTRODUCTION

In the preceding chapter, the author has discussed the curriculum development patterns in general, with specific reference to physics curriculum projects, such as the PSSC project and the Harvard Project Physics Project. These two curriculum projects were discussed in depth, their pros and cons discussed, their relative advantages and disadvantages pointed out. The author also discussed his own reasons for arriving at a unity between these two major curriculum efforts, and the need for filling in the gaps wherever these occur, in order to arrive at a course structure that would not only retain the better aspects of these two courses, but make it more suitable than either one of these or both of these taken together, and serve the needs of the students better at all levels.

The main objectives of this pilot effort on the part of the author, can therefore, be summed up as follows:

1. To design and build a physics program that would take into account the better parts of the PSSC and the HPP course and to arrive at a possible marriage or synthesis between the two courses. This design will take into account other individual curriculum development efforts undertaken elsewhere in North America.

2. To individualize physics instruction within the structure of this pilot course of study, so as to provide for student variation in learning styles, mathematical aptitudes, and interest in topical aspects

of physics.

3. To make the teaching and learning of physics a pleasant and rewarding experience, and thereby arrest the current downward trend in physics enrollments by accomplishing these objectives.

4. To make available to the physics teachers of the province a course from which they would be able to select the topics and materials according to their needs and requirements.

DESIGN OF THE PILOT STUDY

The author intends to use a research-survey-evaluation method in order to arrive at the desired results. He intends to proceed in the following order:

1. The aims and objectives of a general physics education program of studies will be explored and discussed.

2. In the light of these aims and objectives, a critical look will be taken at the physics programs currently being offered, and conclusions drawn.

3. A preliminary framework will then be established, enabling the author to proceed with the development of the pilot project.

4. Within the framework thus established, thorough study will be made of the more recent developments that have been made in regard to curriculum improvements, attempts to individualize physics instruction, and humanize the teaching and learning of physics.

5. An attempt will then be made to arrive at a synthesis between the physics courses being currently offered in the province and the most recent developments in this field, notably the Harvard Project Physics.

6. An attempt will be made to suggest different approaches that could be followed for the purpose of individualizing physics instruction so as to accommodate the needs and aspirations of students with varying degrees of abilities and objectives.

7. And finally, this study will conclude with some suggestions and recommendations for the improvement of the teaching and learning of physics in this province, so as to make it more acceptable by an average high school student.

It is the author's earnest hope that once completed, this study will not only serve the purpose of a thesis, but also serve as an aid to high school physics teachers in this province.

DEVELOPMENT OF THE MODULAR APPROACH

In the opinion of the author, the course structure of the Modular Approach project would consist of the following:

1. Specific aims and objectives,

2. Both basic and optional (advanced in certain cases) required assignments,

3. Tests especially designed to measure the desired objectives, in keeping with the structure of the course (more shall be said in detail about testing as part of this pilot project later on).

4. Lists of school resources related to each unit or module. These might include reference texts, extra reading materials, magazines and periodicals,

5. A "Grade Option Plan" or the point system which would enable each student to select the grade that he/she wishes to obtain and work accordingly,

6. A more and better selection of the laboratory investigations, activities and demonstrations to tie in with this pilot project,

7. A system whereby a student will have the chance of alternative options in the form of additional experiments, worksheets, term papers, book reports or tests to be able to improve upon his/her chosen grade that he/she is working for, in case he/she slips below that grade or wishes to improve upon it,

8. A system of worsheets specifically designed to achieve the aims and objections behind this pilot project. No single textbook can serve the needs of all the students. The author is of the opinion that the classroom teacher should be at liberty to select or make up better and more practical problems from different sources like textbooks, and magazines like the Physics Teacher or other suoh periodicals, or even try and make up some himself, grade these problems in the increasing order of difficulty so that these can then be fitted into the structure of this pilot project.

IMPLEMENTATION

The author intends to implement the course to be developed in his own school during the 1973-74 school year. The necessary materials will be developed as the school year goes along, tested and changes introduced as a result of the experiences gained. The final materials so developed will then form the main part of the project. Since it may not be possible to teach everything during the course of the year because of certain uncertain factors beyond the author's control, some materials may have to be developed without being implemented during the course of the year.

EVALUATION OF THE PILOT PROJECT

This will be accomplished in the following manner:

1. The students involved in the pilot project will be asked to complete a questionnaire regarding their opinions about the pilot project. These results will then be compared with those of students studying the PP course above.

2. Enrollment figures for students studying physics next year will be compared to that of the current year, and,

3. The drop-out rate in physics for this year will be compared to that of last year's.

4. Performance levels of the students studying the Pilot Project will be compared to those of last year's students studying PSSC Physics course.

It is sincerely hoped that the conclusions drawn as a result of these evaluation procedures will be helpful in enabling the author to make certain recommendations regarding the adoption of this MAP Program on a province wide basis.

CHAPTER 4

DEVELOPMENT OF THE MAP MATERIALS

DIFFERENT APPROACHES TOWARDS THE DEVELOPMENT OF THE PILOT PROJECT

The author considered various different approaches for the purpose of developing this pilot project. Whereas the two main courses, the PSSC and the HPP were studied in detail, other curriculum development efforts on a statewide basis, such as in the state of New York, and individual or group efforts at various levels in various parts of the United States in particular were studied, apart from the different approaches followed in some of the popular textbooks. What follows below, is a list of the courses and textbooks consulted for the purpose of arriving at this pilot project.

1. PSSC Course.
2. Project Physics Course.
3. Physics by Genzer and Youngner, approved by the Department of Education.
4. Physics for High School, by Kelly and Miner, also approved by the Department of Education.
5. Concepts in Physics by Miller, Dillon and Smith.
6. Physics - Fundamentals and Frontiers by Stollberg and Hill.
7. Physics - Its Methods and Meanings by Dr. Taffel.
8. Physics by Marantz.
9. Modern Physics by Dull and Metcalff.
10. Development and Implementation of a New Type Program of

Secondary School Physics, A Four-Year, Independent, Individualized, Modular Program, Clayton Public School System, Mo., U.S.A.

11. Coordination of Organic Curriculum Development in the Public Schools of Fort Lauderdale, Florida, U.S.A.
12. Review of Research & Development Program of Project Physics by Wayne W. Welch, University of Minnesota, U.S.A.
13. Physics, A Syllabus for Secondary Schools, The State Department of Education, the University of the State of New York, Albany, N. Y., U.S.A.
14. The Decision Making Process in the Adoption of a New Physics Course in American High Schools, Final Report, by John F. Yegge, Fletscher G. Watson, and Stephen S. Winter, Harvard Graduate School of Education, Cambridge, Mass., U.S.A.

It might be pointed out here, that the two main courses consulted are the PSSC and the Project Physics. The later is currently being piloted by the author in his school under a special permission to try out this course on a pilot basis, by the Department of Education and the Winnipeg School Division Number 1. The other books, courses and reports are being listed since these were used for reference purposes.

After a careful study, involving the author's own experience of teaching both the main courses, the Project Physics course in the two summer institutes in the United States for American high school physics teachers, as well as a result of the extensive consultation work done, (which meant going through most of the other reference materials mentioned above) the author finally arrived at the conclusion that the best approach which could and should be followed in order to arrive at this pilot project and to meet its aims and objectives as set forth in the previous chapter, is to adopt the "Modular Physics Approach".

PHILOSOPHY BEHIND THE STATEMENT OF THE OBJECTIVES OF THIS PILOT PROJECT

The objectives for this pilot project were chosen with the premise that not all students today are inclined towards becoming phyicists or engineers, but they can all benefit from and enjoy learning about the physical phenomena. The statement of these objectives for each unit or module of this new pilot project will help the teacher, in the author's view, to carefully consider in advance what he feels to be the vital concepts and skills to be learned.

MODULAR APPROACH TO PHYSICS (MAP)

Modules (mods) are nothing but learning packages, designed to be used by individuals, or small groups of students working independently. The author's own experience of adopting this system in his own school has convinced him of the fact that such an approach can even work if the teacher were following the traditional approach, with decidedly better results. These modules are an attempt to improve educational environment through individualization. The average module in this pilot project (MAP) is designed so that an average student can finish it is approximately four weeks or less. In this pilot course, many more than the required number of modules are being presented so as to allow the classroom teacher different flow or learning or teaching patterns, depending upon the interest and needs of his particular class.

Modules are also known by various other names such as units or

Learning Activity Packages (LAPS). Each one of these means and conveys the same message, that is, to present the different concepts involved in a certain module that is in a more unified form, while at the same time setting definite objectives, and complete description of the various tools and materials the student is going to need for the purpose of completing the requirements of that module. Such a module is extremely flexible in its approach. Since it gives the students complete information about finishing the requirements for that module besides enabling him to proceed at his own pace and select the grade he wants to work for by choosing the basic or minimum amount of work plus part or all of the optional work required for that module. The following are some of the main features of what the author calls a "Study Guide" that is supplied to each student to guide him through a particular module.

COMPONENTS OF A STUDY GUIDE - MODULAR APPROACH

1. New Concepts to be introduced.

2. Laboratory Work - Experiments and Activities.

3. Selected References - contains a list of approximately ten books and the chapters in these books that are pertinent to a particular module.

4. Advanced References - for those with a high degree of interest in physics, possibly university bound students.

5. Extended Topics - contains a list of topics, directly or indirectly related to the module being studied. Each student can select one or more of these topics in which he/she feels interested, depending upon the grade he/she is working for. The student is required to submit a report (worth two points each - see details of the point system on the

following pages) on the topic/topics selected before the last day set for the completion of that module.

6. Objectives - Setting a list of objectives for studying or teaching a certain module is very important, for these objectives, once put down in writing, provide the criteria by which the materials for the module are selected, content outlined, instructional procedures and demonstrations and experiments developed, and tests and examinations prepared. All these aspects of an educational program are really the means for accomplishing the basic educational purpose.

An obvious purpose of these objectives for each module should be to make clear to the teacher himself, as well as the students what they should be able to do as a result of the instructional program. It must be pointed out here that these objectives can be set by each teacher for his and the students' use, depending upon the local situations. These objectives may be critized, evaluated, revised and modified; objectives may be added or deleted, all with the purpose of arriving at an appropriate set of educational outcomes to meet the needs of local situation and of individual students.

7. A "Grade Option Plan" has been introduced, as a result of which, each student can select the grade (A, B, C, or D) he/she wants to obtain and do the needed amount of work required to obtain that particular grade. Each study guide for each module has a sheet at the end providing the necessary information to the student as to how much work is required to be finished in a particular module for obtaining a particular grade. Under this plan, the course contents, the laboratories, the worksheets, etc., are all classified into two categories - basic and optional.

The minimum requirements of the course include the basic part and part or all of the optional work.

8. Worksheets - Students, under the plan outlined above, no longer do the questions from one particular textbook that they are supplied with. Instead, the better and more practical problems from different textbooks (sometimes eight or ten of these) are selected, graded in the increasing order of difficulty and are numbered. Each student attempts as many worksheets as he/she wants to attempt, depending upon the grade he/she is working for. Fifteen percent of the total credit is reserved for doing the worksheets.

The same system is to be followed for carrying out the laboratory part of the module. The laboratories to be done should be carefully selected after due consideration, and usually more labs should be included than the maximum number required from any student, so that he/she can select the ones he/she likes best. This is the approach followed very successfully in the new Project Physics Course.

9. Extra Work - An average student should be at liberty of improving upon his/her grade, if so desired, after consultation with the teacher. This extra makeup work may take the form of one or more of the following:

(a) Doing more worksheets.

(b) Doing more or alternate experiments.

(c) Writing more reports from the extended topics, or

(d) Writing further tests.

(e) Designing experiments or projects, considered appropriate by the teacher concerned.

10. Testing or Evaluation - The author recommends that a point

system be followed for the purpose of awarding grades to each student. The criteria to be followed would depend upon the teacher concerned. What follows below is a sample of such a point system that could be followed for a particular module:

Grade "A"....................30 points

Grade "B"....................25 points

Grade "C"....................20 points

Grade "D"....................15 points

In addition, grades of A plus, B plus, C plus, and D plus may be awarded to an individual student, depending upon the overall quality of work submitted. It may have to be changed, if the teacher so desires, from one module to the next. Points will have to be alloted to each component of the program of study such as tests, worksheets, reports, laboratory work, etc. Again, these might have to be changed depending upon the number of tests or laboratory reports, etc. What follows is a typical outline for one mudule in which a student is required to write one test, submit a report on one of the extended area topics, submit one laboratory report, and do the required number of worksheets.

(a) 1 point for each 5 percent of the marks on the test.

(b) 2 points for each of the extended topic reports.

(c) 1 point for each of the worksheets finished.

(d) 5 points for each laboratory report, properly written and submitted in time. A student may earn anywhere from 1 to 5 points, depending upon the quality of the work finished in the report.

For example, a student working for grade "A" could obtain the desired grade by following any one of the following options:

Consider the Case of a Student Working for Grade "A":

Plan Number 1

ACTIVITY	MARKS		POINTS
Test	90%		18
Laboratory Report	--		5
Five Worksheets	--		5
One Extended Topic Report	--		2
		TOTAL	30 Points

Plan Number 2

Test	80%		16
One Laboratory	--		4
Six Worksheets	--		6
Two Extended Topic Reports	--		4
		TOTAL	30 Points

Now, consider the Case of a Student Working for a Grade "D":

Plan Number 1

Test	50%		10
One Laboratory	--		3
Two Worksheets	--		2
		TOTAL	15 Points

Plan Number 2

Test	40%		8
One Laboratory Report	--		3
Three Worksheets	--		3
One Extended Topic Report	--		2
		TOTAL	16 Points

As can be readily seen from the plans outlined, a great degree of flexibility is possible. Thus, only by completing the course requirements for a certain module with a high degree of proficiency could a student make an "A", while only by failing to complete a very minimal assignment could a student fail.

Testing can be accomplished by a number of different methods or means. No matter what the means adopted are, questions must be carefully correlated to the stated objectives in the study guide. Some of the commonly used means of testing to date have been the following:

(a) Multiple choice tests - a method used extensively in the Project Physics Course.

(b) Fill in the blank type questions.

(c) Essay type questions - involving derivations of mathematical relationships, definitions, points of difference between two quantities such as mass and weight, centripetal and centrifugal forces, inertial and non-inertial frames of reference, etc.

(d) A system of testing whereby all or most of the above means of testing are combined into one seems to be the most practicable form of testing. A sample test of this type on the "Refraction of Light" module is being reproduced on page 75 with an explanation of the various sections involved.

11. <u>Laboratory Sheets</u> for the various laboratory investigations mentioned in the study guide are included in the study guide, and help the student in carrying out successfully the laboratory part of the module. Such laboratory sheets supply all the information and instructions a student is likely to need while performing the lab.

12. <u>Audio Visual</u> - Under this heading in the studyguide are listed such things as the films to be shown, use of transparencies, film-loops, etc.

13. <u>Teacher Demonstrations</u> - Under this heading, the teacher might like to put down the various demonstrations that he is going to do himself, as part of his teaching plan for a particular module.

It must be pointed out here that all of the thirteen headings as outlined above may or may not be required for every studyguide. An individual teacher might like to, at his discretion, delete some of these if he so desires. Also, the process of preparing a studyguide is a time consuming one, and needs a lot of consultation, planning and thinking on the part of the teacher. But once prepared, in the light of the author's own experience, the teacher would most likely be free from this type of work for the next couple of years, may be with the exception of making minor changes here and there.

By following this studyguide approach, the author is of the view that physics as a subject can be made much more interesting in that it:

(a) Helps to individualize physics instruction by enabling each student to work according to his/her ability.

(b) Makes it possible for practically every student to study physics by making it a highly flexible course because of the introduction of the grade option plan.

(c) Takes the drudgery out of physics by making it more pleasant to study.

A sample studyguide on the module "Refraction of Light" follows:

STUDYGUIDE

MODULE 8 - REFRACTION OF LIGHT

PHYSICS 200

STUDY GUIDE MODULE - 8

PHYSICS AT ELMWOOD

PHYSICS 200

REFRACTION OF LIGHT

(A) NEW CONCEPTS

BASIC (C AND D GRADES)

Refraction - its meaning, laws of refraction. Total Internal Reflection and Critical angle Reversibility of Light. (qualitative treatment only); refraction by prisms - dispersion; refraction of light by lenses - terminology used in studying lenses; image formation by lenses.

OPTIONAL (A AND B GRADES)

Derivation of the following mathematical relationships:

1. $n_1 \text{ Sin } \Theta_1 = n_2 \text{ Sin } \Theta_2$ and $\text{Sin } \Theta_c = \frac{n_2}{n_1}$

2. $\frac{H_i}{H_o} = \frac{f}{S} = \frac{S_i}{f}$

3. $S_i \; S_o = f^2$

4. $\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ (Lensmaker's Formula)

and their use in solving numberical problems.

(B) OBJECTIVES

As a result of the study of the above mentioned new concepts, you should be able to:

1. Demonstrate your ability to perceive relationships among the

principles optics in relation to the contents of this module, by being able to do the following:

(a) Using Snell's law and theory of index of refraction, solve word problems related to the passage of light as it goes from one medium into another. When appropriate, apply the theory of reversibility.

(b) Draw principal ray diagrams of image formation by converging lenses and diverging lenses. Discuss both the differences between image formation by lenses and image formation by spherical mirrors.

(c) Based on the concepts of the variation of index of refraction with color, explain sunlight dispension by a prism. Utilize a refractive diagram of a prism in your explanation.

(C) EXTENDED TOPICS

Suggested below are some topics, directly or indirectly related to this module. Each student can select one or more of the topics in which he/she feels interested, depending upon the grade he/she wants to obtain. The student will be required to submit a report (worth two points each) on the topic(s) selected before the last day set for the completion of this module. The topics are:

1. Optical Instruments (will count as two topics).
2. Eye as an Optical Instrument.
3. Defects of a Human Eye.
4. Atmospheric Phenomena Based Upon Refraction Effects.

5. Practical Applications of Lenses.
6. Lasers.
7. Defects in Lenses.
8. Science and Photography.
9. The Human Eye Versus a Camera.
10. Practical Applications of Total Internal Reflection.

The length of each report can vary between 500-1000 words or more.

(D) SELECTED REFERENCES

1. PSSC - Chapter 13.
2. Project Physics (U.S. edition - unit 4, Chapter 13).
3. Project Physics (Canadian edition - unit 4, Chapter 15 and 16).
4. Physics by Genzer and Younger - Chapter 19.
5. Physics for High School by Kelly and Miner - Chapters 25 and 26.
6. Concepts in Physics by Miller, Dillon and Smith - Chapter 21.
7. Physics - Fundamentals and Frontiers - Chapter 25.
8. Physics - Its Methods and Meanings by Taffel - Chapters 17 and 18.
9. Modern Physics - Chapter 14.
10. Physics by Marantz - Chapter 13.

(E) ADVANCED TEXTS

1. Physics - Principles and Insights by Freeman - Chapter 13.
2. Physics by Resnick and Halliday - Chapter 41.

(F) LABORATORY INVESTIGATIONS

BASIC (To be done by everybody)

1. To trace the path of light through various materials and discover a relationship describing this path (two materials shall be provided for the purpose of this experiment, one liquid and one solid).

2. To study the nature of images formed by a convex lens, and to arrive at a mathematical relationship between the image distance, object distance and the focal length of the lens.

OPTIONAL (For those wanting to do makeup work in order to earn additional points).

1. To study the path of light through a glass prism, and to measure the critical angle for glass.

Note: Pre and post-lab discussion will follow each lab and guidelines in the form of lab sheets shall be provided. The reports must be turned in within two days (this includes the weekend) after the completion of the labs in the laboratory.

(G) TEACHER DEMONSTRATIONS

1. Blackboard optics materials set will be used to illustrate and explain various key concepts involved in this module.

2. Defects of the human eye and their correction by using lenses shall be illustrated with the help of a demonstration model.

(H) AUDIO VISUAL

1. Films: No films are planned to be shown for this chapter.

2. Transparencies: Transparencies will be used to explain image formation in lenses and to illustrate the principles of certain optical instruments.

3. Film-loops: No film-loops are planned to be shown for this chapter.

(I) READING ASSIGNMENT

The following articles in Project Physics Unit 4 Reader will be found to be extremely helpful, students are recommended to take time to go through these articles:

1. Eye and Camera, Page 89.
2. The Laser - What it Does, Page 99.

Besides these two articles, there are books in the library on optics which the students will find to be extremely helpful.

(J) WORKSHEETS

The various worksheets developed for this module are being attached herewith. Consult the "Grade Option Plan" sheet included in this studyguide to see how many of these worksheets you are required to do.

(K) POINT SYSTEM FOR AWARDING GRADES

A point system for awarding grades will be followed. What follows below is a sample of such a point system. Each activity (like tests, labs, reports, etc.) is being allotted a certain number of points as follows:

Grade A	30 points
Grade B	25 points
Grade C	20 points
Grade D	15 points

For example, a student working for Grade A or D could obtain the desired grade by following any one of the following options:

PLAN NO. 1 (Grade A)

Activity	Points
Test marks - 90%	18
1 lab report	5
5 worksheets	5
1 extended topic report	2
TOTAL	30

PLAN NO. 1 (Grade D)

Activity	Points
Test marks - 50%	10
1 lab report	3
2 worksheets	2
TOTAL	15

PLAN NO. 2 (Grade A)

Activity	Points
Test marks - 80%	15
1 lab report	4
6 worksheets	6
2 extended topic reports	4
TOTAL	30

PLAN NO. 2 (Grade D)

Activity	Points
Test marks - 40	8
1 lab report	3

3 worksheets	3
1 extended topic report	2
TOTAL	16

As can be seen, various combinations are possible, and a student can chart out the best possible combination to suit his/her needs.

(L) COMPLETION TIME

Four weeks maximum.

SUGGESTED DIVISION OF THE POINTS FOR AWARDING GRADES

(a) 1 point for each 5% of the marks on the test score.

(b) 2 points for each of the reports on the extended area topics.

(c) 1 point for each worksheet done.

(d) 5 points for each lab report, properly written and submitted in time. A student may earn anywhere from 1 to 5 points depending upon the quality of the work done in the lab report.

Note: Teachers who do not wish to follow the point system for evaluation purposes, might like to adopt the "Grade Option Plan" described on the next page.

PHYSICS AT ELMWOOD

GRADE OPTION PLAN

Grade to Be Earned	Test Average	Worksheets & Problem Work	Lab Work	Background Readings & Term Papers
A	B	Basic and all Optional Problems	All basic and two Optional Expts.	Four Reports
A	A			Three Reports
B	C	Omit one Optional Problem	All Basic and one Optional	Two Reports
B	A or B			One Report
C	D	Basic Problems Only	Basic Experi- ments	
C	C			None
C	A or B			
D	D		Minimum Lab Work (Consult Teacher)	

NOTE: The grade option plan as outlined above is a suggested plan. However, variations from this plan are possible, and sometimes, even desirable. For instance, grades of A plus, B plus, C plus and D plus, may be given at the discretion of the teacher based on overall quality of work submitted. Where situations permit, the suggested grade option plan may be changed in terms of the work required to obtain a particular grade. This will be done after mutual consultation between the teacher and the individual student. Students should feel free to discuss such a change with the teacher, if they so desire.

The author has tried this system in his own school and his experience over the first three terms of the school year has convinced him beyond any doubt that this system is a workable one, and the students' reaction thus far has been beyond expectations.

In the opinion of the author, some of the other advantages that were found in this approach are listed below:

1. Advantages to the Student
   - (a) Choice of grade, individualized work.
   - (b) Control over grade.
   - (c) Personal contact with teacher.
   - (d) Developing sense of responsibility and self-reliance.
   - (e) Time at school for class work and extra projects.
2. Advantages to the Teacher
   - (a) Freedom from everyday lecture drudgery.
   - (b) Students aiding other students.
   - (c) More effective occasional lectures, films and demonstrations.
   - (d) Completion of work by every student.
   - (e) Constant check on each student's progress.
   - (f) Lessening of discipline problems.
3. Advantages to the Administration
   - (a) A more careful and better planned program.
   - (b) Increased physics enrollment leading to a more well rounded use of science facilities.
   - (c) Economy of equipment costs due to requiring a smaller number of each type of apparatus.

A FURTHER NOTE ABOUT TESTING AND EVALUATION

In keeping with the plan as outlined above, the testing and the evaluation program will have to be tailored to meet the requirements of the new plan. The author is suggesting that the following plan or one similar to this one be followed to make testing an effective part of the entire program.

The physics testing program should be a series of question and problem sets directed towards the following goals:

1. To stimulate further learning.

2. To measure the extent of the student's progress.

3. To evaluate the learning and instructional techniques involved.

4. To ensure that the evaluation program has been designed as a powerful learning aid and an integral part of the student's foundation in physics. It should help the student to increase his overall grasp of physics and to develop potential for effective thinking and problem solving. The program should also motivate learning and develop skills in organizing concepts, applying concepts, and thinking beyond the scope of the prescribed course of studies. It should also make it more interesting and rewarding for an average student to write tests, rather than make them boring and something that a student doesn't really want to write, but has to because he is being forced into it.

Each module of this new pilot physics project, called "MAP", or the Modular Approach to Physics, should be covered by a four part test. These parts are as follows:

PART "A"

DISCOVERING CONCEPTS: This part should include a series of questions directed basically at the fundamental concepts studied in a particular module. This way, it is to be hoped that, the basic or fundamental concepts, ideas and definitions will be reinforced. This section of the test may also help the teacher to discover students' areas of conceptual weakness.

PART "B"

UNDERSTANDING CONCEPTS: This section will contain, for the most part, questions similar in one way or another to the ones wherein the students are required to select one of the several choices. Questions in this section will be a bit harder as compared to Part A. In this section, the student is encouraged to develop his ability to think abstractly. He must understand the material of the module.

PART "C"

USING CONCEPTS: This section is probably the most important of the whole test. In this section, the student will be required to apply the concepts and skills learned in the module to solve mathematical problems. Some of the problems will be similar to the ones in the worksheets, whereas others might involve deeper understanding on the part of the students.

PART "D"

EXTENDING CONCEPTS: The questions in this section can be answered only by a student who has thoroughly mastered the contents of the module. The student will have to have a thorough understanding of the various concepts involved and be able to apply them in situations which are more abstract. This section is meant for and should stimulate and excite the more capable and bright students. Since the questions would tend to be difficult, hints may be supplied to help start off a student on the right track. In short, this section proves to be a challenge for the advanced students.

As can be seen, the plan outlined above provides ample opportunity for every student to earn a passing grade by doing the basic amount of work. As the student does more and more of the optional work, he/she will be able to obtain a higher percentage of marks by attempting questions in parts C and D of the test. A sample test on the module "Refraction of Light" is being provided here for the guidance of the teachers concerned and to help them develop similar tests for themselves. Changes may be necessary and even desirable, depending upon the situation.

SAMPLE TEST

PHYSICS AT ELMWOOD

TEST

MODULE NO. 8 - REFRACTION OF LIGHT

NAME OF STUDENT: ______________________

TEST SCORE: ______________________

PERCENTAGE SCORE: ______________________

AVERAGE CLASS SCORE: ______________________

TEST

MODULE NO. 8

PHYSICS AT ELMWOOD

REFRACTION OF LIGHT

SECTION A - DISCOVERING CONCEPTS

1. The Dutch scientist, ________________, first discovered the relationship between the angle of incidence and the angle of refraction.

2. When light travels from one transparent substance into another transparent substance, it is convenient to use a ____________ index of refraction to determine the angle of refraction.

3. The ______________ angle is that angle of incidence that causes the refracted ray to lie right along the boundary of the substance.

4. A piece of glass (usually triangular) used to disperse light is called a ________________.

5. A ______________ lens is thickest at its middle and becomes thinner toward its edges.

6. Circle the factors that determine the focal length of a lens:

   Shape   Material lens is made from   Object Distance   Index of Refraction

7. Circle the letter that could be a virtual image of an object placed to the left of the lens below:

   A   B

8. Circle the pair of characteristics that describe the images formed by a diverging lens:

   virtual erect   real enlarged   virtual enlarged   real reduced

9. Circle the pair of characteristics that describe the image formed by the objective lens of a telescope.

virtual enlarged	real enlarged	virtual reduced	real reduced

10. The eyepieces of optical instruments produce enlarged, erect, real images of the image produced by the objective lens.

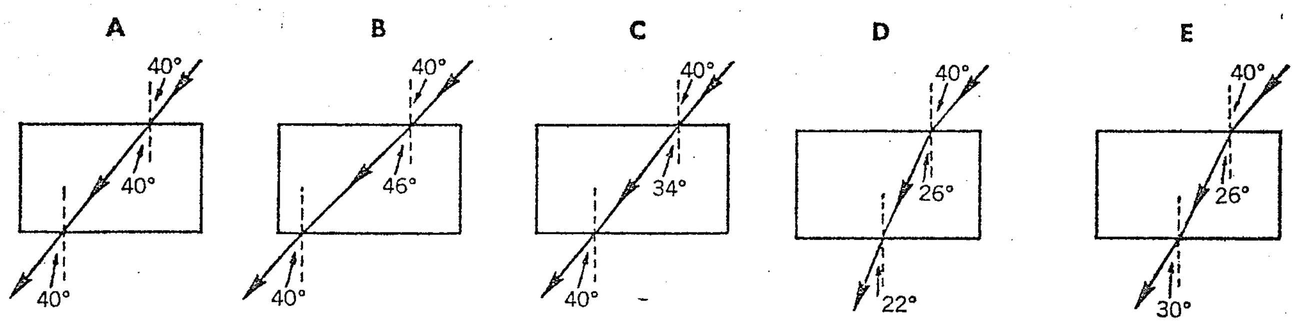
T F

SECTION B - UNDERSTANDING CONCEPTS

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

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

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



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

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

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

4. The block of glass is placed in liquid 1 in such a way that only its lower half is submerged. 4. ______

5. The block of glass is placed in liquid 3 in such a way that only its lower half is submerged. 5. ______

6. Draw in the approximate refracted rays in the two diagrams below

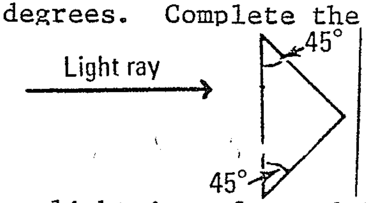
7. The index of a refraction is a ratio of the ____________ of the incident and refracted angles.

sines cosines tangents semi-chords

8. Total internal reflection can occur when a light ray goes from a less dense substance into a denser substance.

T F

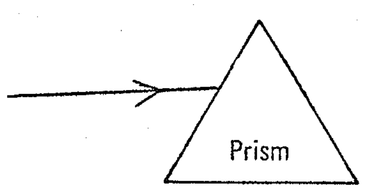
9. The critical angle for light leaving glass and going into air is approximately 42 degrees. Complete the ray diagram found below:



10. ________________ light is refracted least by a prism.

red green orange blue yellow

11. Complete the following ray diagram. The critical angle is not exceeded.



SECTION C - USING CONCEPTS

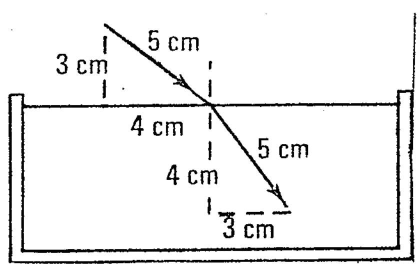
1. A ray of light enters crown glass at an incident angle of 40 degrees. Calculate the angle of refraction. The index of refraction of crown glass is 1.52.

2. The angle between a beam of light entering water from air and the surface of the water is 60 degrees. The index of refraction of water is 1.33.

   (a) What is the angle of reflection?

   (b) Calculate the angle of refraction.

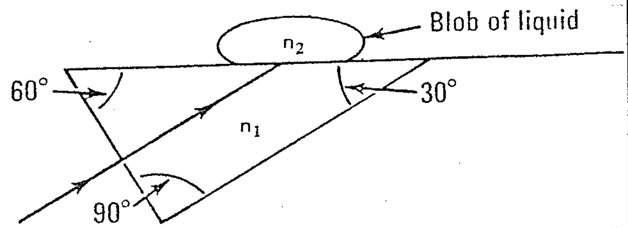
3. In the figure below, a ray of light enters the liquid and is bent toward the normal as shown. Calculate the index of refraction for the liquid.



4. Calculate the relative index of refraction for light going from a diamond into water. The absolute index of refraction for water is 1.33 and is 2.42 for diamond.

5. A ray of light normal to the short face of a 30-60-90 prism is shown below. A blob of liquid is placed on the hypotenuse of the glass prism. The index of refraction of glass is 1.50. Calculate the maximum index of refraction that the liquid can have if the light ray is to be totally internally reflected.

Diagram for Question 5.

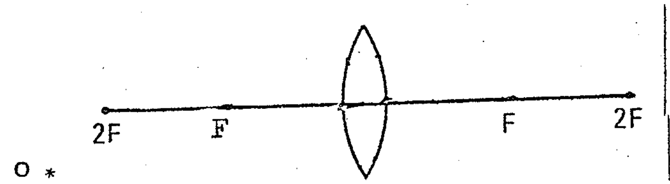


6. A light beam makes an angle of 60^{o} to the normal as it strikes a transparent substance. Part of the beam is reflected from the surface into the air and part is refracted through the substance. The reflected and refracted beams make an angle of 90^{o} with each other.

   (a) Calculate the index of refraction of the substance.

   (b) Calculate the critical angle for light leaving this substance and and going into a material with an index of refraction of 1.30.

7. Draw a ray diagram below to locate the image of object*.



SECTION D - EXTENDED CONCEPTS

1. A large tank is filled with alcohol to a depth of 12 cm. A small light source is placed at the center of the bottom of the tank. Alcohol has an index or refraction of 1.36. Calculate the area at the surface of the alcohol through which the light will pass. HINT: Remember the concept of total internal reflection and critical angle.

2. A beam of light is directed from air through a successive parallel layers of glass, water, polyethylene, and alcohol. Try to prove that the refracted angle of the beam as it leaves the alcohol and re-enters air depends only on the initial incident angle from air into the glass. In other words, show that the order and type of intermediate materials do not affect the answer. HINT: Draw a diagram and consider what happens at the two surfaces of each material.

3. Snell's original equation for determining index of refraction involved a ratio of semichords. Can you show that this is equivalent to a ratio of sines? HINT: Draw a refraction diagram and draw a circle around it so the point where the normal intersects the surface of the material is the center of the circle. The semichord will then be a line drawn from the circle perpendicular to the normal.

4. Try to explain why the sun appears more red at sunset. Why does the sky appear blue? Who do astronauts on the moon see a black sky? HINT: Consider which wavelengths of light would be scattered or diffracted by air molecules more easily.

The format of this sample test, as well as most of the questions in the test are selected from the evaluation program in physics, designed by M/S Murphy and Smoot as part of their physics program that accompanies their test, titled, "Physics - Principles and Problems", published by Charles E. Merril Publishing Company, Columbus, Ohio.

Presented on the following pages are samples of a student lab sheet and a progress report card which the author uses in his school as part of the new Pilot Project.

A SAMPLE LAB - INSTRUCTION SHEET

LAB SHEET | EXPT. E-I

K I N E M A T I C S

MODULE NO. 2 | GRAPHICAL ANALYSIS OF MOTION

Name: ______________________________ Room: __________

Date Experiment Performed: __________________

Date Experiment Turned In: __________________

NOTE: This is an instruction sheet only. You are required to submit a proper lab report.

The experiment itself does not take very long to complete, but its analysis requires care and patience. The following guidelines are being provided to facilitate this analysis.

MOTION: VELOCITY AND ACCELERATION

> "Nothing in nature is more ancient than motion, and the volumes that the philosophers have compiled about it are neither few nor small; yet have I discovered that there are many things of interest about it that have hitherto been unperceived."
>
> ......Galelio Galilei (1564-1642)

EQUIPMENT NEEDED:

1 Ruler

4 Sheets Rectilinear Graph Paper

1 Weight (about 200-250 gm)

1 Recording Timer

1 C-Clamp (3" or 4")

INSTRUCTIONS RE: ANALYZING THE EXPERIMENT

(A) In his lab-investigations, you will analyze the varying motions of a body moving in a straight line. This will be done with the aid of a recording timer. You will use the timer tape to analyze your own speed and acceleration as you walk by freely with one end of the tape in your hand.

1. While you are pulling the tape through the timer, walk as you would normally do, swinging your arm. Construct your own set of graphs.

2. About 2 metres of tape will be sufficient to get 25-30 points on the graph with 5 "ticks" as the unit of time.

3. You must begin work on the graphs (v and x versus t) in class and then continue it at home.

4. It is not necessary to know the calibration of the timer for this experiment; any unit of time is good. Taking 5 "ticks" as the unit of time speeds up the analysis. (See the diagram)

5. Set up a table of velocity as a function of time from which you can plot velocity versus time. However, the graphs of position versus time and acceleration versus time should be plotted from the velocity versus time graph.

6. The average velocity is obtained by measuring the displacement from the first to the last mark on the tape and dividing this by the number of time units (5 "ticks").

7. After you are through with what has been said above, prepare a velocity versus time graph by cutting tape into lengths corresponding to the displacement in equal time

intervals and pasting these side by side on a common line. Compare this with the velocity versus time graph plotted earlier in (5) above. Then, make an acceleration versus time graph by measuring the successive Δ v's on the velocity-time graph and cutting tape lengths equal to them. (Just measure and cut the tape by putting it besidesthe bars on the velocity-time graph). Paste all the Δ v's side by side to form the acceleration plot and compare it with the acceleration time graph plotted earlier. This will help you to visualize better what the measurements and the graphs mean.

(B) FINDING THE ACCELERATION DUE TO GRAVITY:

By direct fall, using the same equipment as above, start the timer and let the object fall. Repeat steps 5, 6 and 7 as in Part "A", and plot the three graphs. Find the acceleration due to gravity by finding the slope of "v" versus "t" graphs.

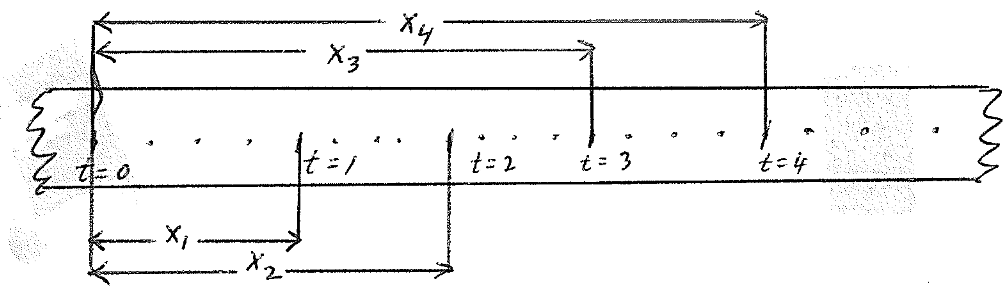
(C) CALIBRATING THE TIMER:

If you want time measurements in seconds, calibrate the timer as follows:

Take another long piece of tape approximately one meter long (or more) and thread it through the timer. Start the timer, using a stopwatch in one hand, and with the tape in your other hand, begin pulling the tape and start watch at the same time. Pull the tape for exactly 5 seconds and then stop. To find the length of the time interval between dots, Δ t. We must assume that the timer vibrates at a constant rate. If it does, then the time interval Δt, in seconds, is given by

$$\Delta t = \frac{\text{5 seconds}}{\text{No. of intervals in 5 seconds}}$$

As shown in the figure below, while the timer makes 5 dots, it makes 4 intervals.



You might now like to change your already calculated values of speed and acceleration in terms of cm/sec^2. After you have calculated the value of a_g in cm/sec^2, ask for the standard value of a_g from your teacher, and calculate the percentage error.

MEASURING THE TAPE

If you find the first few points on your tape are too crowded together, you might like to disregard a few of these points.

REMEMBER: 1. The first dot you start counting, has to be labelled, 0 (zero)

2. Each student makes his/her own sets of tapes.

OTHER METHODS USED TO FIND THE VALUE OF a_g

1. With slow motion photography (a film-loop for this purpose is available in the laboratory).

2. From a pendulum, by timing the swinging of a pendulum.

3. From falling water drops (Project Physics course).

4. With strobe photography (PP Course).

NOTES:

1. Each student will be allowed a maximum of three days to complete this lab, write a suitable lab report, and plot all the graphs.

2. No student should try to copy the data from somebody else.

3. Below each graph (or, at the back) write a brief explanation.

4. This experiment is a basic experiment and has to be completed by each student.

5. In all, there will be three graphs ("d" vs. "t", "v" vs "t", and "a" vs. "t" for part (A) of the experiment, and similar three graphs for part (B) of the experiment.

6. Organize your data for each graph in a tabular form and put it at the back of each graph.

7. Besides the six graphs as mentioned above, there will be two additional graphs as mentioned in step number 7 of part (A) of the experiment.

8. While writing the lab report, the usual format should be followed, i.e., should include the following:

(a) Abstract*.

(b) Purpose.

(c) Background and Related Literature*.

(d) Procedure.

(e) Data and Analysis.

(f) Error Analysis.

(g) Assumptions.

(h) Summary or Conclusions.

(i) Discussion (optional).

(j) Selected References*.

* Needed for scientific report but not for laboratory report.

PHYSICS AT ELMWOOD

STUDENT PROGRESS

RECORD CARD

1. Student's Name: ______________________ Room Number: ________

2. Course: ________________

3. Textbook: ________________

NOTE: This card must be carried by the student at all times during each Physics class

MODULE NUMBER	TOPIC	RECORD OF WORK DONE				DATE OF COMPLETION	OVERALL GRADE	TEACHER'S SIGNATURE
		WP	L	R	T			
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

A SAMPLE OF A PROGRESS REPORT CARD

EXPLANATION OF SYMBOLS OR CODES USED IN THE PROGRESS REPORT CARD

KEY

WP	-	Worksheets and Problem Work
L	-	Laboratory Work
R	-	Background Readings Including Term Papers
T	-	Test
B	-	Basic Work Satisfactory
BU	-	Basic Work Unsatisfactory
R	-	Repeat
BO	-	Basic Work and Optional Satisfactory
OU	-	Optional Work Unsatisfactory

THE MAP COURSE OUTLINE

MODULE NO. 1 - MEASUREMENT AND PHYSICS

STUDY GUIDE

MODULE - 1

PHYSICS AT ELMWOOD

PHYSICS 200

MEASUREMENT AND PHYSICS

(A) NEW CONCEPTS

BASIC

Physics as the most fundamental science, its relation to other sciences - fundamental and applied; basic and derived quantities; systems of measurement; metric system of measurement; accuracy in measurement; scientific notation; units of length mass and time; advantages of metric system; slide rule and graphing techniques; significant figures; orders of magnitude; different methods and instruments or techniques employed in the measurement of length, mass and time.

NOTE: Some of the topics suggested above might be taken by classroom teacher in the form of lab investigations or as part of other labs, instead of dealing with them as separate topics in the regular classroom lessons.

OPTIONAL

Stroboscope and stroboscopic techniques; scaling.

(B) OBJECTIVES

1. Using scientific notation, solve given work problems that involve measurements of time and require calculations and/or experiments.

2. Solve given word problems that involve measurements of distance area, and volume and require calculations and/or

experiments. Express the results in significant figures.

3. Be able to multiply, divide, add, and subtract numbers in scientific notation; also, be able to carry out calculations using a slide rule.

4. Be able to round off numbers to the proper number of significant digits.

5. Be able to graph one variable against another, properly label the graph, given a table of data in two variables.

6. Be able to write up an experiment in a manner such that someone else with a high school background in science can quickly and correctly determine what the student has done and what the results were, using only the student's write-up and the lab manual. Minimum contents of the write-up should include:

    1. Title and name of the experiment.
    2. Objectives and procedure (procedure might not be desirable in certain cases).
    3. Applicable sketches.
    4. Data with applicable tables and proper units.
    5. Interpretations with applicable graphs and/or equations clearly identified and labelled.
    6. Always a conclusion capturing the essence of the experiment, supported by data (which in some instances may have to be borrowed).

7. The student should have a working familiarity with the metric system of units, and be able to convert units from

English to the metric system. Following are some of the exercises the like of which an average student should be able to handle most of the time:

(a) Length of a football field in meters and in kilometers.

(b) Distance of the moon from the earth in metric units.

(c) Average speed limit of a family car on a highway in meters/sec. and kilometers/hr.

(d) Volume of a gas tank or an engine of a car in liters.

(e) Volume of a jug of milk in liters, milliliters and cc's.

(f) The mass of the student in kilograms and grams.

(g) The mass of a penny in grams and kilograms.

(h) Boiling and freezing point of pure water in degrees centigrade.

(i) The body temperature of a normal healthy person in degrees centigrade.

(j) The most comfortable range of temperatures to be maintained in a house in degrees centigrade.

(D) LABORATORY INVESTIGATIONS

Since this module deals with measurement, any lab work done here should mainly emphasize the objectives mentioned above. With that end in mind, the following are some of the more stimulating and interesting lab investigations which the teacher concerned might like to carry out. Again, these are being classified into two categories:

1. BASIC

To measure the acceleration due to gravity by using one of the following methods:

(a) By direct fall, using a recording timer (PSSC).

(b) By using a pendulum.

(c) By direct fall, using battery light, strobe disc and a polaroid camera.

(d) Using the counter/timer, and photo-electric cells. (A film-loop about the last method is available from Thornton Associates, Inc., and so is the required equipment. Interested teachers can find out more about this and other fascinating pieces of equipment by writing to the company whose complete address is given in the appendix at the end).

2. Analysis of data (from PSSC lab guide).

1. OPTIONAL

To study the use of a stroboscope and to use the stroboscope in measuring the frequency of a vibrating bell clapper (from the PSSC lab guide).

NOTE: Besides these experiments, the students should be familiarized with other measuring equipment available in the laboratory. More emphasis should be laid upon the use of such basic measuring devices such as a meter stick, a balance, timers, etc.

(E) TEACHER DEMONSTRATIONS

If the school has an electronic stroboscope available, the teacher concerned can do some interesting demonstrations which tends to dramatize the use of a stroboscope. These include stopping the motion of the blades of an electric fan by shining light on these blades from a stroboscope, or doing the same thing with falling water drops.

A film-loop (from the Project Physics Course) dramatizes the effects of slow motion in an extremely vivid manner. It's called "Drops and Splashes".

(F) AUDIO VISUAL

The following PSSC films may be shown depending upon their availability and the availability of time:

1. Measurement of Short Distances.
2. Measurement of Large Distances.
3. Measurement of Short Time Intervals.
4. Measurement of Long Time Intervals
5. Change of Scale.
6. Time and Clocks.

TRANSPARENCIES

A set of printed originals on slide rule instruction is supplied by the 3M Company from which the transparencies can be easily made in the school office. Also, Pickett Inc., of California supplies slide rules at discount prices to schools ordering 48 slide rules or more and as a bonus, sends a free transparent slide rule with nine scales on it for use with the overhead projector.

NOTE: One of the extremely useful and inexpensive books available for the purpose of teaching this module is, "Terms, Tables and Skills", published by Silver Burdett Company. This book deals with about 15 chapters on various aspects of measurement, units and accuracy and graphing techniques as well as writing lab reports. It has also got at the end a set of 28 tables with values of different constants. All in all, a very useful little book that most teachers might even like to prescribe, or, order a few copies for the school library.

(G) COMPLETION TIME

Four to five weeks.

MODULE NO. 2 - KINEMATICS OF MOTION

STUDYGUIDE

MODULE - 2

PHYSICS AT ELMWOOD

PHYSICS 200

KINEMATICS OF MOTION

(A) NEW CONCEPTS

BASIC

Rest and Motion - absolute and relative; kinematics and dynamics; distance and displacement; uniform and non-uniform motion; speed and velocity - difference between them; scalar and vector quantities; acceleration-average and instantaneous; graphical analysis of motion; motion of freely falling bodies; ideas of terminal velocity; use of vectors to add and subtract velocities and displacements.

OPTIONAL

Mathematical derivation of the following equations of motion:

1. $v_f = v_i + at$
2. $d = v_i t + \frac{1}{2}at^2$
3. $v_f^2 = v_i^2 + 2ad$

and their use in solving numerical problems. Introduction of new mathematical concepts of limits in defining instantaneous speed, velocity and acceleration; derivation of above mathematical relationships from the graphs to stress the correlation between graphical and mathematical analysis of motion.

(B) EXTENDED AREAS

A period or two may be set aside for a discussion on Aristotelian concepts of motion versus Galilean concepts of motion, and impact of Galileo's work upon modern science pointed out, or, it may be set aside as one of the topics on which students might like to do some reading and write reports on short term papers. Some such topics suitable for such reports and related to this module, directly or indirectly, are the following:

1. A Biographical Sketch of Galileo.
2. Galileo's Struggle with the Church.
3. Impact of Galileo's Work Upon Modern Science.
4. Aristotelian Versus Galilean Concepts of Motion.

(C) LABORATORY INVESTIGATIONS

BASIC

1. Free fall as an example of illustrated motion - to measure the value of acceleration due to gravity by using a recording timer, using graphical techniques.
2. To analyse the motion of a laboratory cart by the graphical method.

OR

To analyse the motion of a person (the student) walking normally by using graphical techniques.

OPTIONAL

1. Teachers in schools where a polaroid camera and an electronic stroboscope is available can use the strobe photography method to find the value of acceleration due to gravity.

2. Project Physics film-loops are a very effective way of doing some of the labs. For the purpose of this module, the following film-loops are suitable. (The students enjoy working on these film-loops very much):

   1. Acceleration Due to Gravity - I.
   2. Acceleration Due to Gravity - II.
   3. Vector Addition - Velocity of a Boat.
   4. A Matter of Relative Motion.
   5. Galilean Relativity - I, Ball Dropped From the Mast of a Ship.
   6. Galilean Relativity - II, Object Dropped From an Aircraft.
   7. Galilean Relativity - III, Projectile Fired Vertically.
   8. Analysis of a Hurdle Race - I.
   9. Analysis of a Hurdle Race - II.

(D) FILM-LOOPS PROVIDE THE FOLLOWING ADVANTAGES

The situations portrayed in these film-loops are, in most cases, real and have been first photographed as they actually happen, and then in slow motion, so that the student can, by using the slow motion factor given in the film-loop, and by using a timer, complete the analysis usually in 15-20 minutes. Each of these film-loops runs for 3-4 minutes, is self-winding, and can be easily operated by an average student by inserting it in a film-loop projector. Additional equipment needed, as mentioned already, is a film-loop projector, and some place to do the film-loop such as a blackboard or a wall with a sheet of white paper taped on it. The film-loops can be used in several ways to demonstrate some concepts or to let a student or students work on a lab on their own. Most teachers in the United States using these film-loops like to use these loops as student activities.

COST FACTORS

The only disadvantage in using the film-loops is the cost factor. Each of the film-loops costs nearly twenty dollars, and the projector itself costs nearly $150.00. This problem can be very easily overcome if materials like film-loops, projectors, polaroid cameras, stroboscopes, etc., are purchased on a division wide basis. Of course, if the individual schools can afford the items out of their regular school budget, nothing like it. Moreover, the fact that these materials are being mentioned in these modules does not mean in any way that their use is inescapable. The author is of the opinion that these things should be known to each physics teacher concerned so that it is entirely up to him to see if he wants to make use of them, and if so, how can he go about getting them. Whereas the use of such items in the teaching and learning of physics will certainly enhance the quality of education, their non-availability should certainly prove no handicap to anyone concerned. Also, it is quite possible that some schools might already own some of these pieces of equipment. Moreover, if a teacher feels interested, he can gradually order all or some of these items, depending upon his choice and needs. The names and addresses of the places to be contacted for getting additional information about these items is being provided in the appendix at the end of this paper.

(E) ADDITIONAL READING

PROJECT PHYSICS READER UNIT I ARTICLES

1. Motion in Words.
2. Motion.
3. Representation of Movement.
4. Introducing Vectors.

(F) AUDIO VISUAL

The following PSSC films will be found to be useful for this module:

1. Straight Line Kinematics.
2. Vectors.

Transparencies: Project Physics Unit I.

(G) COMPLETION TIME:

Four to five weeks.

MODULE NO. 3

DYNAMICS OF MOTION - NEWTON EXPLAINS MOTION

"Force is one of the ghostly quantities of Physics".

.... Sir Albert Einstein

"The whole burden of philosophy seems to consist in this - from the phenomenon of motions to investigate the forces of nature, and then from these forces to explain other phenomena".

.... Sir Isaac Newton

STUDY GUIDE MODULE - 3

PHYSICS AT ELMWOOD

PHYSICS 200

DYNAMICS OF MOTION - NEWTON EXPLAINS MOTION

(A) NEW CONCEPTS

BASIC

Difference between kinematics and dynamics; Aristotelian explanation of motion; concept of force and inertia; Newton's laws of motion (first and second); vector addition of forces; relation between force, mass and acceleration; motion in earth's gravitational field; free fall; mass and weight, circular motion (qualitative treatment); Earth satellites - natural and artificial (qualitative); centripetal and centrifugal forces (qualitative treatment only).

OPTIONAL: QUANTITATIVE TREATMENT OF THE FOLLOWING:

Circular motion, projectile motion, simple harmonic motion - motion of a simple pendulum (derivation of the equation for the time period); frames of reference and relativity.

(B) OBJECTIVES

The purpose of studying this module should be to meet the needs of the following objectives:

1. To demonstrate the properties of force and the ways in which properties interact.
2. Given a description of force, clarify the force as a vector quantity.

3. To study the dependence of force upon mass and acceleration, and to arrive at a quantitative relationship between these three quantities.
4. To further explore and verify the application of Newton's second law of motion in case of other types of motions such as projectile, circular and simple harmonic motions.
5. To seek a better understanding of the principle of operation of the satellites and the uses of which they are put.
6. To emphasize the importance of relative motion and frames of reference in describing different types of motion.
7. To be able to prove at least two of the following without reference:

   (a) $F_c = mv^2/R$

   (b) $T = 2\pi\sqrt{l/g}$

   (c) $T = 2\pi\sqrt{m/k}$

   (d) That a trajectory of a projectile is a parabola.

(C) EXTENDED TOPICS

1. Significance of Newton's laws.
2. Nature's basic forces.
3. Weightlessness.
4. Using Newton's laws.
5. Satellites and mankind.
6. Newton's laws and sports.
7. Fictitious forces.
8. Frames of Reference.

(D) EXTENDED READING

(a) PSSC Science Study Series.

(b) Project Physics Reader Unit I Articles:

1. Introduction to Vectors.
2. Newton's laws of Dynamics.
3. The Scientific Revolution.
4. How the Scientific Revolution of the 17th Century Affected Other Branches of Thought.

(E) LABORATORY INVESTIGATIONS (Any three of the following:)

(a) To find the value of acceleration due to gravity by anyone of the methods described below:

1. By using a simple pendulum.
2. By direct fall.
3. With slow motion photography (Project Physics film-loop).

(b) To plot curves of trajectories in case of an object describing projectile motion, and to analyse this motion (PP).

(c) To study the relationship between force, mass and acceleration by using either the PSSC method (using bricks, cart and rubber loops) or the PP method of using a cart, spring balance, blinky, photographic meter stick, pulley and a polaroid camera.

(d) 1. To study the relationship between mass and weight.

2. To study the relationship between inertial and gravitational mass.

(F) AUDIO VISUAL

The following films (PSSC) should be shown, depending upon their availability and the availability of time. The use of these films is highly recommended:

1. Inertia.
2. Inertial Mass.
3. Deflecting Forces.
4. Periodic Motion.
5. Frames of Reference.

Transparencies: Project Physics Unit I.

(G) COMPLETION TIME:

Four to five weeks.

MODULE NO. 4

MOTION IN THE HEAVENS OR UNIVERSAL GRAVITATION

STUDY GUIDE

MODULE - 4

PHYSICS AT ELMWOOD

PHYSICS 200

MOTION IN THE HEAVENS OR UNIVERSAL GRAVITATION

(A) NEW CONCEPTS

BASIC

Historical development of the concept of the solar system as understood today, starting from the time of ancient Greeks until the time of Newton; discussions of the contributions made by astronomers such as Tycho Brahe, Copernicus, Kepler and Newton; Kepler's laws of planetary motion and Newton's law of Universal Gravitation - importance of these laws.

OPTIONAL

Use of Kepler's and Newton's law in modern space science; structure of the universe; Einstein and relativity in relation to the structure of the universe. Use of Kepler's law of elliptical orbits in atomic science. Use of these laws in their mathematical form to solve numerical problems.

(B) EXTENDED TOPICS

Because of the wide scope of the material that can be dealt with in this unit, each student should be required to write a term paper or an essay on at least one of the following topics:

1. Weightlessness.
2. Frames of Reference.
3. General Relativity.

4. Newtonian Physics vs. Modern Physics.
5. Newton's Place in Modern Science.
6. Newton's Classical Synthesis of Earthly and Celestial Mechanics.
7. The Growth and Development of Scientific Thought in the Fifteenth, Sixteenth and Seventeenth Centuries.
8. The Universe of Newton vs. the Universe of Einstein.
9. Our Dear Earth - Through the Centuries.
10. A Spaceship Tour of the Solar System.
11. The Universe Beyond the Solar System.
12. A Scientific Theory vs. Theories of Celestial Motion.
13. The Modern Space Exploration Program and the Works of Kepler, Galileo and Newton.

(C) LABORATORY INVESTIGATIONS

"To plot the orbit of the earth's motion around the sun." (PP) This experiment can be done simply with the aid of a sun-film strip that is available at a nominal cost of only four dollars. The experiment is worth the time the students will spend on it, and after plotting the orbit the students can then use Kepler's laws to calculate the value of orbital eccentricity of the Earth or even verify the laws of planetary motion.

(D) READING ASSIGNMENT

If possible, each student should be encouraged to read Unit II of the Project Physics course. This is highly recommended. The author's experience has been that putting about five copies of each of the six units in the library proves to be quite helpful. Students who are interested in reading about physics find the project physics materials easy to go through and enjoy them at the same time.

(E) AUDIO VISUAL

FILM-LOOPS

The film-loop on Kepler's laws is also a good way of doing the lab activity. By projecting the film-loop on paper, the student may check Kepler's laws by marking the successive planetary positions of two computer generated orbits of two planets moving around the sun. Very highly recommended. (PP)

FILMS

The following two PSSC films may be shown, if available:

1. Elliptic Orbits.
2. Universal Gravitation.
3. Universe. (National Film Board of Canada's award winning film).

TRANSPARENCIES

Project Physics Unit II transparencies, if available.

(F) COMPLETION TIME:

Three to four weeks.

MODULE NO. 5

MOMENTUM AND CONSERVATION OF MOMENTUM

STUDY GUIDE MODULE - 5

PHYSICS AT ELMWOOD

PHYSICS 200

MOMENTUM AND CONSERVATION OF MOMENTUM

(A) NEW CONCEPTS

BASIC

Momentum and impulse; Rewriting Newton's second law, F = ma, to define these two quantities and emphasize their vector nature and their units; Conservation of momentum in relation to bodies moving and colliding along straight lines; Different types of collision-elastic and inelastic; Effects of balanced and unbalanced forces on a system; Newton's third law of motion.

OPTIONAL

Discussion of glancing or off-center collisons, and graphical solution of such problems in relation to the law of conservation of momentum; Conservation of momentum in general. Center of mass.

PRACTICAL APPLICATIONS

Examples like those of billiards, curling, bowling, crouquet, tennis, hockey etc., should be brought in to clarify the key concepts in this module. The author uses curling as the main illustration to teach most of this module and later on, this can then be extended to collisions on the highways. The significance of such things as collapsible bumpers and bumper guards can be explained by using $F.\Delta t = m.\Delta v$. In some cases, the teacher might like to arrange a visit to the curling rink and explain the physics of curling. In short, this whole module can be built aroung the things students are already exposed to, such as the above mentioned situations.

(B) LABORATORY INVESTIGATIONS

BASIC

To study the law on conservation of momentum by observing the abrupt separation of two carts (momentum changes in an explosion).

OPTIONAL

To study collisions in two dimensions and to observe the law of conservation of momentum in such collisions. (Some teachers might like to show the PSSC film, "Collisions of Hard Spheres" before starting this experiment).

OTHER LABORATORY TECHNIQUES

Depending upon the availability of facilities and materials, one or more of the following techniques can be used as part of the lab work for this module:

(a) For one dimensional collisions, strobe disc or a strobe flash photo of two exploding dynamics carts with a polaroid camera can be taken. The same technique can be repeated with colliding air-track gliders.

(b) For two dimensional collisions, strobe disc or strobe flash photographs of colliding pucks or disc magnets can be taken.

(C) AUDIO VISUAL

FILM-LOOPS

The following Project Physics film-loops can be used as the basis for laboratory experiments:

(a) Elastic Collisions:

1. One dimensional Collisions - I*.
2. Two dimensional Collisions - II.

(b) Inelastic Collisions:

1. Inelastic one dimensional collisions.
2. Inelastic two dimensional collisions.

(c) Two dimensional collisions, Parts I and II*.

* Highly recommended.

Teachers using or wishing to use these or some of these film-loops can ask the students to retain their tracings for the next module on energy when these could be used again for verifying the law of conservation of kinetic energy. These film-loops are meant to be used for both the modules on momentum and energy.

An Important Note: Teachers who don't wish to buy these film-loops, can make use of the photographs from these film-loops given on pages 154-160 of the Project Physics Unit - 3.

(D) COMPLETION TIME - 4 to 5 weeks.

MODULE NO. 6

ENERGY AND ITS CONSERVATION

"It's love that makes the world go round" - Ancient Ditty

"Energy makes the world go round. Energy explains everything."

- Modern dity to be found in general science books.

STUDY GUIDE MODULE - 6

PHYSICS AT ELMWOOD

PHYSICS 200

ENERGY AND CONSERVATION OF ENERGY

PRE-REQUISITE: MODULE NO. 5 ON MOMENTUM

(A) NEW CONCEPTS

BASIC

Work and Kinetic Energy; Derivation of the relationship $F \cdot d = \frac{1}{2}mv^2$, or, $W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$; Potential energy; Clarification about the forces that do no work; Conservation of mechanical energy and statement of the law of conservation of mechanical energy; Energy in biological systems like plants and human beings; Energy Conservation on earth and its importance; Conservation of kinetic energy in elastic and inelastic collisions.

OPTIONAL

Different kinds of potential energy-Gravitational and spring potential energy; Derivation of $U_g = mgh$ and $U_s = \frac{1}{2}kx^2$; Escape and binding energy; Other different forms of energy; Conservation of energy from one form into another; A precise and general statement of the law of energy conservation.

(B) EXTENDED TOPICS

Because of the recent interest in energy, this module will lend itself highly suitable for the purpose of writing extended topic reports. Although only mechanical energy has been touched upon in this module, teachers will still find a great deal of interest on the part of the students who wish to study some aspect of the energy crisis in detail. Some of the possible topics for this purpose are being suggested below:

(C) LABORATORY INVESTIGATIONS

BASIC

FILM-LOOPS

The following film-loops are from the project physics course. All the film-loops meant for this module are being mentioned below. However, the teachers might like to go for the ones marked with an asterick, since these, in author's view are especially useful as lab exercises:

1. Finding a speed of a rile bullet*.
2. Conservation of energy-pole vault and aircraft take-off*.
3. Recoil.
4. Colliding freight cars.
5. Dynamics of a billiard ball.
6. Gravitational P. E.
7. Kinetic Energy.
8. A method of measuring energy-nail driven into wood.

OPTIONAL LAB EXPERIMENTS

The following experiments on this module tend to quite difficult and beyond the reach of an average student. For such students, the film-loops are suggested. For brighter students one or more of the following two experiments may be conducted:

1. Energy changes in a stretched spring - To study the relationship between spring P. E. and the change in Gravitational P. E. of the attached mass. (This is a PSSC experiment).
2. Elastic Collisions and Stored Energy - To analyse the motion of two magnets of equal mass undergoing of off-centered collision. This can be treated as an activity rather than as an experiment. Before this activity is carried out, it might be worthwhile to show the film, "Elastic Collisions and Stored Energy", a PSSC film. If facilities permit, a stroboscopic photograph of the collision may be taken by using an airtable, failing which, a print of such a photograph may be handed out to each student. Such prints can be purchased in the form of a package of 25 from Macalaster Scientific at a nominal cost of a few dollars per package. The print in this case is a photograph of one of the experiments carried out in the above mentioned film.

(D) EXTENDED READING

Project Physics Reader Unit III articles:

1. The steam engine come of age.
2. The great Conservation Principles.

<u>PSSC Science Study Series:</u>

1. Gravity.

<u>Project Physics Unit III:</u>

1. Slow collisions.

2. The watt engine.

(E) Completion time: five weeks

MODULE NO. 7.

REFLECTION OF LIGHT

STUDY GUIDE

MODULE - 7

PHYSICS AT ELMWOOD

PHYSICS 200

REFLECTION OF LIGHT

(A) NEW CONCEPTS

Introduction - Terminology used in studying light; Reflection of light, Formation of shadows and eclipses; Binocular vision; Laws of reflection; Images in plane mirrors; Properties of images in plane mirrors; Mirrors inclined at angles to each other; Parabolic mirrors and spherical mirrors; Image formation in spherical mirrors; Defects in spherical mirrors; Application of mirrors in searchlights and telescopes; Mathematical relationships connecting the focal length, object distance, the image distance, the size of the object and the size of the image.

(B) LABORATORY INVESTIGATIONS

1. To study parallax and light reflection describing their location. (PSSC experiment II-1).
2. To determine the nature of images formed by a concave mirror and a relationship describing their location. (PSSC experiment II-2).

(C) AUDIO VISUAL

A set of printed originals on reflection of light, made by 3M Company will be found to be highly useful, from which transparencies can be made in the school.

MODULE NO. 9

INTRODUCTION TO WAVES

STUDY GUIDE MODULE - 9

PHYSICS AT ELMWOOD

PHYSICS 200

INTRODUCTION TO WAVES

PRE-REQUISITE: MODULE NO. 1

(A) NEW CONCEPTS

BASIC

Introduction; Importance of the study of waves as one of the two modes of energy transfer from one point to another; Difference between a wave and a pulse; Properties of a wave; Different types of waves-transverse, longitudinal, periodic, etc., Propogation of waves; Definition of the basic terms used in studying waves-amplitude, wavelength, frequency etc., Relationship connecting the speed of propogation of a wave, its frequency and wavelength, Principles of superposition; Diffraction and interference of waves (qualitative treatment only); $v = f\lambda$

OPTIONAL

Huyghen's wave theory; explanation of the various wave phenomena in terms of the wave theory or the wave model; Standing waves; Derivation of the following mathematical relationships:

1. $\sin i / \sin r = v_1/v_2 = \lambda_1/\lambda_2 = n_{12}$
2. $\lambda = x \cdot d/L$
3. $\sin \theta_n = (n-\frac{1}{2})\lambda/d = x/L$, OR $\lambda = \frac{d \cdot x/L}{(n-\frac{1}{2})}$

(B) EXTENDED READING

(a) Project Physics Unit III Reader Articles:

1. Silence, Please.
2. Waves.
3. What is a Wave?

(C) LABORATORY INVESTIGATIONS

Most of the material in this module can be built around the laboratory work. The following experiments are specially useful:

(a) Using ropes, springs or slinkies, to investigate simple properties of waves and wave behaviour, including the following:

1. To study the properties of wave pulses in a linear medium.
2. To study the transmission and reflection of waves.
3. To produce standing waves in a linear medium and study their properties.

(b) Using a Ripple Tank:

1. To study the production, propogation and reflection of plane and circular waves from straight and circular barriers.
2. To produce and measure the characteristics of straight waves.
3. To study the refraction of waves.
4. To study the effects of openings and obstacles on the travel of plane waves, and,

5. To study the interference pattern produced by two inphase periodic point sources.

(D) AUDIO VISUAL

1. Films: The PSSC film on waves should be shown.
2. Film-loops: An excellent series of 8 mm film-loops, covering the entire range of experiments involving the ripple tank is available and can be substituted (if available) in place of all or some of the ripple tank experiments. The following are the film-loops that could be used:
   (a) Straight wave reflection from straight wave barriers.
   (b) Circular wave reflection from various sources.
   (c) Reflection of waves from circular barriers.
   (d) Refraction of waves.
   *(e) Doppler effect.
   *(f) Formation of shock waves.
   (g) Superposition of pulses.
   (h) Interference of waves.
   *(i) Effect of phase difference between sources.
   (j) Single slit diffraction.
   *(k) Multiple slit diffraction.
   *(l) Diffraction and scattering around obstacles.

*Optional

OTHER FILM-LOOPS (OPTIONAL):

1. Standing waves on a string.

2. Standing waves in a gas.
3. Vibrations of a rubber hose.
4. Vibrations of a drum.
5. Vibrations of a wire.
6. Vibrations of a metal plate.

Alternatively, the teacher might just like to set up one ripple tank in good working condition in the class, and by using a device called "The vertical viewer" (available from Macalaster Scientific), demonstrate the various properties of the waves. This device enables the students to see the various properties of waves as if they were watching the film-loops.

3. Transparencies:

   (a) A set of printed originals on "waves" by 3M Company will be found to be extremely useful, and transparencies can be made from the originals in the school.

   (b) Project Physics Unit III set of transparencies on Chapter 12.

(E) <u>COMPLETION TIME</u>

Four weeks.

MODULE NO. 10

INTRODUCTION TO SOUND

STUDY GUIDE

MODULE - 10

PHYSICS AT ELMWOOD

PHYSICS 200

INTRODUCTION TO SOUND

PRE-REQUISITE: MODULE NO. 9 ON WAVES.

(A) NEW CONCEPTS

BASIC

Sound as a form of energy; Propogation of sound through a material medium; Production of sound; Transmission of sound through air in the form of compressions and rarefactions; Speed of sound and effect of factors such as temperature, wind velocity, humidity, etc., on the speed of sound; Sonic spectrum; Infrasonic and ultrasonic sounds; Noise and music; Characteristics of a musical sound-loudness pitch and quality; Harmonics and overtones; Types of noise; Qualitative discussion of the relationship between intensity and loudness-decibel level of sounds; Frequency and pitch; Resonance; Beats; Standing waves; Noise and environment; Decibel levels due to different sounds encountered in day-to-day life; Effect of noise on hearing power; Graphical representation of sound.

OPTIONAL

Mathematical study of the relationship between intensity and loudness; Introduction of the equation; $\beta = \log \frac{I}{I_o}$

Sound pressure level; The Doppler Effect; The Human ear; Acoustics; Sonic Booms; Laws of vibration of strings - the physics of stringed musical instruments; The laws of vibration of air columns - the physics of wind musical instruments; Forced and sympathetic vibrations.

(B) EXTENDED TOPICS

1. Noise - The Jet Age Pollution.
2. Noise and Environment.
3. Noise and Music.
4. Acoustics.
5. Physics of musical instruments.
6. Noise and Hearing Losses.

(C) TEACHER DEMONSTRATIONS

If the teacher has access to instruments such as an oscilloscope, an amplifier, a sine wave generator, speakers and a microphone, the following demonstrations will be found to be extremely stimulating:

1. Using the above mentioned equipment to demonstrate the wave patterns due to a tuning fork of a certain frequency, to enable students to see music displayed on the oscilloscope screen and let them observe the harmonics in music, to explain the difference between noise and music, to explain the relationship between speed, wavelength and frequency, the inverse relationship between frequency and wavelength

to demonstrate the range of sound frequencies to which a normal human ear is sensitive. Students who are members of the school band could be asked to bring the various instruments they play, and ask to play a note or a tune and see the sound pattern on the oscilloscope.

2. In case the teacher has no access to these things, he could simply show the oscillograms due to certain musical instruments which are given in various books, and thereby explain concepts such as harmonics, overtones, etc.
3. A ripple tank could be used to demonstrate concepts such as standing waves, Doppler Effect, etc.,
4. A slinky could be used to demonstrate the propogation sound in the form of compressions and rarefactions.

(D) LABORATORY INVESTIGATIONS

BASIC

1. Ask students to write about (if they have seen music on the oscilloscope) their observations about the various demonstrations done with the oscilloscope. This should be counted as an activity, worth about half the credit of that of a regular lab.
2. Behaviour of sound - an experiment using a sine wave generator, an amplifier and a loudspeaker. To study the behaviour of sound-transmission, reflection, absorption-refraction, diffraction, and interference of sound (A Project Physics experiment). Pages 95-97 of Physics - A

Human Endeavour, the Canadian Version of the Project Physics, Unit 4.

3. Speed of Sound, a Project Physics experiment using practically no lab equipment. Experiment 14.2, Unit 4 of Physics, A Human Endeavour (henceforth to be referred as CPP - Canadian Project Physics. The original U. S. edition will be referred to as PP - for Project Physics.)

OPTIONAL

1. To find the speed of sound at room temperature by using the resonance method. Experiment No. 14.3, page 98, Unit 4, CPP.
2. To investigate the laws of vibration of strings using a sonometer. Experiment No. 14.7, page 103, Unit 4, CPP.

(E) AUDIO VISUAL

(a) Film-loops:

1. Doppler Effect.
2. Shock Waves.
3. The series of film-loops on ripple tank.
4. Tacoma Narrows Bridge Collapse - an interesting example of mechanical resonance. An excellent film-loop that will convince any student about the fact that any structure could vibrate at its own natural frequency.

(b) Films:

1. Sound waves in air (PSSC).

2. Approaching the speed of sound, in color, available free of charge from Shell Oil Company, 50 W, 50th St., N. Y.

3. Sound waves and their sources, available from Encyclopedia Britannica (EB).

4. The Sounds of Music, Coronet Films, Inc., 65 E.S. Water Street, Chicago.

(F) EXTENDED READING

1. Sound Waves and Light Waves (PSSC Science Study Series).
2. Waves and Messages (PSSC Science Study Series).
3. Echoes of Bats and Men (PSSC Science Study Series).
4. Horns, Strings and Harmony (PSSC Science Study Series).
5. Noise, an article in Scientific American, Dec. 1966.
6. Waves and the Ear (PSSC Science Study Series).
7. Sound: From Communication to Noise Pollution, Doubleday.
8. Sound and Hearing (Life Science Library) Time Inc., N. Y.
9. The following articles are from The Science Teacher:
   (a) Determining the frequency of a vibrating String, Mar.65.
   (b) Projecting Sound Waves and Beats on the Oscilloscope, Dec. 57.
   (c) Hearing is Believing or is it? - May 68.
   (d) The velocity of Sound, Feb. 64.
10. Demonstrations of Reflection and Diffraction of Sound, The Physics Teacher, May 68.
11. Following articles from PP unit 3 Reader:

(a) Wave Motion and Acoustics.

(b) Musical Instruments and Scales.

(G) COMPLETION TIME

Four to five weeks.

MODULE NO. 11

THE NATURE OF LIGHT

STUDY GUIDE MODULE - 11

PHYSICS AT ELMWOOD

PHYSICS 200

THE NATURE OF LIGHT

PRE-REQUISITE: MODULE NOS. 7 and 8

(A) NEW CONCEPTS

BASIC

Recapitulation of the properties of light as covered in the modules on reflection and refraction of light; Explanation of these properties of light behaviour in terms of the particle model of light; Recapitulation of the properties of waves in general as discussed in the module on waves; Explanation of these properties of light in terms of the wave model or wave theory; Comparison of the two models: speed of light; Brief recapitulation of the significant development in the history of measuring the speed of light; Recounting to include Galelio, Roemer, Huyghens, Maxwell, Fizeau, Ether and Michelson/Morley; Importance of the speed of light in nature; Interference and diffraction of light; Young's experiment; Photometry or the measurement of light and the inverse square law of light.

OPTIONAL

Newton's corpuscular theory and Huyghen's wave theory in detail; Single slit and double slit interference pattern; Color and wavelength of light; Derivation of the following mathematical relationships:

1. $\lambda = 2 \times d/l$

2. $\lambda = \quad \times d/l$

Difference between interference and diffraction patterns; Theory of diffraction by a slit; Resolution; Interference in thin films; Polarization of light; Light and color; A comparison, the effects of single and double slits on light.

NOTE: The following film-loops will be found to be extremely helpful in dealing with the optional part of this module:

1. Single slit diffraction (of water waves).
2. Diffraction - single slit (of light).
3. Diffraction - double slit (of light).
4. Resolution of light.

(B) LABORATORY INVESTIGATIONS

BASIC

(a) Young's experiment - to study the pattern of light produced when it passes through double slits, and determine the wavelength of light of different colors (PSSC).

(b) To study the interference pattern produced by a single slit and to compare it with the 2-slit pattern.

OPTIONAL

(a) To determine the thickness of a thin material such as aluminum foil, using the interference of light of known wavelength, and if a sodium light source is available, to find the wavelength of sodium light by this method (PSSC) or (PP).

(C) TEACHER DEMONSTRATIONS

The following demonstrations can be very easily carried out in the class without much difficulty by way of any lack of equipment:

1. To demonstrate the diffraction of light using two fingers and an illuminated showcase bulb.
2. To demonstrate refraction of particles (PSSC).
3. To demonstrate the formation of Newton's rings as an illustration of interference effects in thin films.
4. To demonstrate the meaning of polarized and non-polarized light by using two polarized filters of polarized sun glasses.
5. The "Cornell interference and diffraction slits" may be used to let students observe for themselves the various kinds of patterns that result when a student looks at a straight filament showcase bulb through the various single, double and multiple slits of varying widths.
6. If a photometer or a light meter is available, these may be used to demonstrate the inverse square law of light.
7. Using a thin soap film, the teacher might like to demonstrate the interference pattern produced when light is reflected from a thin soap film.

(D) AUDIO VISUAL

(a) Films:

1. People and Particles (Project Physics).
2. Speed of Light (PSSC).
3. Pressure of Light (PSSC).

4. Laser Light (Scientific American), an excellent film.

(E) EXTENDED READING

(a) Project Physics Unit IV Reader Articles:

1. Experiments and calculations relative to physical optics.

2. Velocity of Light.

3. Popular applications of polarized light.

(b) PSSC Science Study Series:

1. Light Waves and Sound Waves.

(F) COMPLETION TIME

Five weeks.

MODULE NO. 12

THE KINETIC-MOLECULAR THEORY

STUDY GUIDE MODULE - 12

PHYSICS AT ELMWOOD

PHYSICS 200

THE KINETIC-MOLECULAR THEORY

PRE-REQUISITE: MODULE NOS. 3 AND 6

(A) NEW CONCEPTS

BASIC

Introduction; Kinetic Molecular Theory of Heat (Qualitative treatment only); Brief recapitulation of the kinetic-molecular theory of gases, Boyle's law; Heat and Temperature-difference between the two on the basis of the K-M Theory; Temperature and molecular kinetic energy; Internal Energy; Heat flow from bodies at higher to lower temperatures, Relationship between heat and work-Joule's mechanical equivalent of heat; kelvin scale and absolute scale of temperature; ideal gas law; entropy.

OPTIONAL

Mathematical treatment of the following: Derivation of a equation for the pressure exerted by a gas [$(P = \frac{2}{3}\frac{E}{K}(\frac{N}{V})$] Mathematical Relationship between temperature and kinetic energy; Thermodynamics and the laws of thermodynamics; Second law of thermodynamics and dissipation of energy; Detailed discussion of Entropy and the statement of the second law of thermodynamics in terms of entropy; Energy conservation in general; A general statement of the law of conservation of Energy; Maxwell's demon and the statistical view of the second law of thermodynamics; Conservation of energy on the earth; Energy in biological systems.

(B) LABORATORY INVESTIGATIONS

BASIC

1. Temperature and Thermometers-qualitative experiment involving "defining a temperature scale", comparing thermometers, etc., Experiment No. 26, page 180, Unit 3, PP.
2. Calorimetry: The following experiements could be included in this category;
   (a) To observe the conservation of thermal energy during heat transfer.
   (b) To employ the law of conservation of energy as a means of measuring the specific heat of a metal.
   (c) To use the law of conservation of energy as a means of measuring the latent heat offusion of a solid (ice) or the latent heat of steam or both.

(C) EXTENDED TOPICS

1. Conservation of Energy.
2. Energy-Use or Misuse?
3. Sources of Energy.
4. Conservation of Energy on a Global Scale.
   Conservation of Energy on a National Scale.
   Conservation of Energy on a Provincial Scale.
5. Energy and Mankind.
6. Our life Without Energy.
7. Energy Conservation in the Universe.

(D) EXTENDED READING

1. The following articles relevant to this module are from PP Reader Unit 3:

   (a) The Steam Engine Comes of Age.

   (b) The Great Conservation Principles.

   (c) The Barometer Story.

   (d) The Great Molecular Theory of Gases.

   (e) Entropy and the Second Law of Thermodynamics.

   (f) The Law of Disorder.

   (g) The Law.

   (h) Arrow of Time.

   (i) James Clark Maxwell.

   (j) Randomness and the 20th Century.

2. The following are the PSSC Science Study Series titles:

   (a) Count Rumford.

   (b) Water-The Mirror of Science.

   (c) The Neutron Story.

   (d) Near Zero.

   (e) Heat Engines.

3. "Plasma-The Fourth State of Matter", The Physics Teacher, January, 1970.

4. Science by Degrees, Walker and Company, N.Y.

5. Gases and Plasmas, Lippincott, Philadelphia, Penn., U.S.A.

(E) AUDIO VISUAL

Films:

1. PSSC Film: Mechanical Energy and Thermal Energy.

2. Conservation of Energy, PSSC film.

3. An Introduction to Heat Engines, available from Shell Oil Company, free, 50 W. 50th Street, N.Y. 20, N.Y.

(F) <u>COMPLETION TIME</u>

Three weeks.

MODULE NO. 13

ELECTRIC CHARGES AND ELECTRIC FORCES

STUDY GUIDE

MODULE - 13

PHYSICS AT ELMWOOD

PHYSICS 200

ELECTRIC CHARGES AND ELECTRIC FORCES

PRE-REQUISITE: MODULE NO. 3

(A) NEW CONCEPTS

Introduction to elementary electrostatic phenomena-two kinds of charges, attraction and repulsion, electroscopes, conduction and induction etc.; General Concept of a force field; Electric fields and their properties; Coulomb's law of electric force between charged bodies; unit of electric charge; elementary electric charge-Millikan's experiment; Conservation of charge; Electric Potential difference and electric current-their units; Ohm's Law; Electric power; Relation between P.D., current and power; Batteries and EMF; The derivation and explanation of the following equations.

(B) LABORATORY INVESTIGATIONS

BASIC

1. Static Electricity-To observe and account for the behaviour of bodies bearing static electric charges, including the behaviour of the pithball in an electric field and experiments with the electroscope.
2. Experiment 34-Electric Forces 1 (PP).

NOTE: Any one of the two may be carried out.

3. Experiment 35-Electric Forces II-Quantitative study of Coulomb's Law (PP).

OR

4. The PSSC Experiment on Coulomb's Law.

NOTE: Whereas the PSSC experiment requires commercial Coulomb's law apparatus, the PP version of the same experiment can be easily improvized in the laboratory.

5. Millikan's Experiment-A qualitative study of the relationship between terminal velocity and the driving force (PSSC).

OPTIONAL

Experiment 42 (PP)-The quantitative measurement of the charge on an electron by using the Millikan's experiment.

(C) EXTENDED TOPICS

1. Scientific Priority and Coulomb's Law.
2. Electricity and Society.
3. Conservation of Electricity.
4. Faraday and the Electrical Age.
5. Modern Life without Electricity.
6. Hydro-Electric Power or A Modern Electric Power Plant.
7. Particle Accelerators-Instruments for Basic Research and Human Welfare.

(D) EXTENDED READING

(a) PSSC Science Study Series:

1. Near Zero.
2. Physics of T.V.
3. Knowledge and Wonder.
4. Soap Bubbles.

5. Electrostatics.

(b) PP Unit 4 Reader Articles:

1. Radiation Belts Around the Earth.

2. A Mirror for the Brain.

(E) AUDIO VISUAL

Films:

(a) Electric Fields (PSSC).

(b) Coulomb's Law (PSSC).

(c) Coulomb's Law Force Constant (PSSC).

(d) Millikan's Experiment (PSSC).

(e) Electric Lines of Force.

(F) COMPLETION TIME

Four weeks.

MODULE NO. 14

MAGNETIC FIELDS AND MAGNETIC FORCES

STUDY GUIDE MODULE - 14

PHYSICS AT ELMWOOD

PHYSICS 200

MAGNETIC FIELDS AND MAGNETIC FORCES

PRE-REQUISITE: MODULE NO. 13

(A) NEW CONCEPTS

Introduction-the curious properties of lodestone and amber; Gilbert's "De Magnete"; Magnetic needle; Magnetic fields of magnets and currents; Vector addition of magnetic fields; Forces on currents in magnetic field; Unit of magnetic field strength-gauss; Derivation of F = I.1.B; Right and left hand rules; Electric motors and electric meters; Forces on moving charged particles in a magnetic field (qualitiative); Alpha particles; Magnetic field near a long st. wire.

OPTIONAL

Using magnetic field to measure the masses of charged particles; Uniform magnetic field-Mathematical expression of a uniform magnetic field inside a coil - $B_{\underline{1}} = 2\ KNI$; Earth's magnetism. Forces on moving charged particles in a magnetic field (mathematical).

(B) LABORATORY INVESTIGATIONS

1. Current balance-the force between moving charges, i.e., between electric currents. To investigate the effect of the magnitudes and directions of the currents by using a current balance. Experiments number 36 and 37 in PP. Although an experiment on the current balance is also included in the PSSC lab guide, the one in the PP course is much better from the point of view of clarifying the concepts it is supposed to do.
2. Mapping a magnetic field-To have the students map or plot a magnetic field, due to a single magnet and then due to two magnets with their similar or opposite poles facing each other. The students are highly motivated because they enjoy this experiment very much. The two methods of using iron filings and compass needle could both be used effectively.
3. Tangent Galvanometer-To show that the magnetic field create by a current is proportional to that current.

NOTE: Any two of the above mentioned experiments could be carried out by an average student. Students wishing to earn extra credit do more of them after consultation with the teacher concerned.

OPTIONAL

Experiment number 38-investigations with an electron beam tube (PP).

(C) TEACHER DEMONSTRATIONS

The teacher could carry out the following demonstrations in the class to clarify certain concepts in this module:

1. Magnetic effects associated with electricity; involving magnetic field around a wire and the magnetic field of a coil.

2. Additional activities using the electron beam tube, page 160 unit 4, PP.

(D) AUDIO VISUAL

Films:

1. A Magnet Laboratory (PSSC).

2. Electrons in a Uniform Magnetic Field.

3. Magnetism (Encyclopedia Britannica).

4. Ferromagnetic Domains (Bell Telephone Labs).

5. The formation of ferromagnetic domains (Bell Telephone Labs).

(E) EXTENDED READING

(a) PSSC Science Study Series:

1. Rutherford and the Nature of the Atom.
2. Magnets-The Education of a Physicist.
3. The Universe at Large.
4. Faraday, Maxwell and Kelvin.
5. Electrons and Waves.
6. Knowledge and Wonder.
7. Accelerators.

(b) PP Reader No. 4 Articles:

1. Systems, Feedback and Cybernatics.

2. The Electronic Revolution.

3. The Invention of the Electric Light.

4. High Fidelity.

5. The Future of Direct Power Transmission.

(c) Free Materials Relevant to this module:

1. Magnetism and Electricity, 34 pages, undated, free, Chrysler Corporation, P.O. Box 1919, Detroit, Michigan. How magnetism helps us to understand the electrical conditions of our automobiles.

(d) The following articles from The Scientific American:

1. Galvanomagnetic and Thermomagnetic Effects, December, 61.

2. Magnetic Monopoles, December, 1963.

3. Ferrites, June, 62.

4. Superconducting magnets, June, 62.

5. Strong Magnetic Fields, February, 58.

Non-uniform electrical fields, December, 60.

(e) The following articles from the The Science Teacher:

1. Magnetics, November, 1967.

2. Construction of a simple meter, September, 57.

3. Electric Forces-laws of ampere and Oersted, Vol. 28, No. 3.

(f) The following articles from The Physics Teacher:

1. Faraday and the field concepts in physics, May, 68.

2. Why keepers on magnets, January, 68.

(F) COMPLETION TIME

Four weeks.

MODULE NO. 15

ELECTRO-MAGNETIC RADIATION

STUDY GUIDE MODULE - 15

PHYSICS AT ELMWOOD

PHYSICS 200

ELECTRO-MAGNETIC RADIATION

PRE-REQUISITE: MODULE NO. 14

(A) NEW CONCEPTS

BASIC

Introduction; Induced currents; Discovery of e.m. induction by Faraday; Generating electricity by the use of magnetic fields- the dynamo; AC versus DC; Maxwell's formulation of the principles of electro magnetism; The propogation of electro-magnetic waves (qualitative treatment only); Hertz's experiments; The electro-magnetic spectrum; The place of ether at this stage.

OPTIONAL

Magnetic flux change; Induced e.m.f. and its direction; Electric fields around changing magnetic fluxes; Mathematical explanation of the mechanism of e.m. radiation; evidence for e.m. radiation.

(B) EXTENDED TOPICS

1. Radio and T.V. Signals.
2. Radio and T.V. Broadcasting.
3. Transmission of Electromagnetic Energy From one Place to Another.
4. Electromagnetic waves and moder space research.
5. Amplitude Modulation and Frequency Modulation.
6. Radio Telescopes and Modern Astronomy.

NOTE: An excellent chart on electromagnetic spectrum published by the Westinghouse Electric Corporation (cost $3.00) can be obtained by writing to their Canadian head office in Hamilton, Ontario.

(C) LABORATORY INVESTIGATIONS

Waves and Communications: PP experiment number 39, unit 4-to enable students to see how the wave phenomena are used in communications. The PP experiment suggests different pieces of equipment, all of which essentially serve the same objective-how we can communicate with waves. Depending upon the availability of equipment, all or one of the following may be used:

1. Turntable oscillators.
2. Resonant circuits.
3. Microwave generator and other related pieces of equipment. This is highly recommended and is probably the best out of three suggested methods and the students enjoy doing this experiment, very much. Thornton Associates (address is given in appendix 1) supplies a complete set of Microwave equipment.

(D) AUDIO VISUAL

Film:

1. Electromagnetic Waves (PSSC).

Film-loop:

1. Standing electromagnetic waves.

Transparency: The Electromagnetic Spectrum, PP Unit 4 set of transparencies (if available).

(E) EXTENDED READING

1. Project Physics Reader Unit 4.
2. Physics of T.V. (PSSC SSS).
3. Waves and Messages (PSSC SSS).
4. Quantum Electronics (PSSC SSS).
5. Electrons and Waves (PSSC SSS).
6. Computers and the Human Mind (PSSC SSS).
7. Accelerators (PSSC SSS) and B. Faraday, Maxwell and Kelvin.

(F) COMPLETION TIME

Four weeks.

MODULE NO. 16

ATOMIC STRUCTURE OR MODELS OF THE ATOM

STUDY GUIDE MODULE - 16

PHYSICS AT ELMWOOD

PHYSICS 200

ATOMIC STRUCTURE OR MODELS OF THE ATOM

PRE-REQUISITE: MODULE NUMBER 15

(A) NEW CONCEPTS

BASIC

Introduction-Recapitulation of the chemical basis of the atomic theory*; The idea of atomic structure; Sir J.J. Thompson's experiments on cathode rays; (The students might at this stage be reminded about the Millikan's experiment regarding the measurement of the charge on the electron); Spectra of gases-spectrum analysis; Emission and absorption spectra; Regularities in the hydrogen spectrum; Rutherford's nuclear model of the atom; Nuclear charge and size; The Bohr Theory (qualitative); The size of the hydrogen atom.

*Most of the students would already have had some exposure to the atomic theory, particularly if they are also studying chemistry or have studied it. In any event, the teacher might like to spend some class time, say two or three periods, going over the main points of the atomic theory.

OPTIONAL

Detailed study of the hydrogen spectrum; Postulates of Bohr's theory; Bohr's quantization rule and the size of the orbits; Consequences of the Bohr model; The Bohr theory-the spectral lines of hyrogen atom; Stationary states of atom-The Frank-

Hertz experiement; Shortcomings of the Bohr Theory.

(B) EXTENDED TOPICS FOR READING

(a) PSSC Science Study Series:

1. An Approach to Modern Physics.
2. Rutherford and the Nature of the Atom.
3. The Restless Universe.
4. The Neutron Story.
5. Knowledge and Wonder.
6. Accelerators.
7. Perpetual Motion: Electrons and Atoms in Crystals.

(b) Project Physics Reader No. 5 Articles:

1. The teacher and the Bohr Theory of the Atom.

(c) The following Articles From The Physics Teacher:

1. Elementary particles, January 64.
2. Robert Millikan-The physicist who changed the course of history, January, 64.

(d) The Following Articles From The Scientific American:

1. Atomic Clocks, February, 57.
2. The Atomic Nucleus, July, 56.
3. The Nuclear Force, March, 60.
4. The Neutron, October, 51.
5. What is Matter, September, 53.

(C) LABORATORY INVESTIGATIONS

1. Mass of an electron-PSSC experiment.
2. Spectroscopy, experiment no. 44, PP unit 5 (highly recommended).

3. The Spectrum of Hydrogen (PSSC experiment IV-15).

(D) AUDIO VISUAL

(a) Films:

1. Crystals, PSSC.
2. The Rutherford Atom, PSSC.
3. Mass of the Electron, PSSC.
4. Counting Electric Charges in Motion, PSSC.
5. Electrons in a Uniform Magnetic Field, PSSC.

(b) Film-loop: Rutherford Scattering (PP).

(c) Transparencies: Alpha Scattering (PP) and Energy Levels-Bohr Theory (PP).

(E) EXTENDED TOPICS

1. A Historical Development of the Structure of the Atom.
2. Atomic Theory in the early 1920's.
3. The periodic table of the elements.
4. A biographical sketch of Rutherford.
5. A biographical sketch of Neils Bohr.
6. Spectroscopy and the Atomic Structure.

(F) COMPLETION TIME

Four weeks.

MODULE NO. 17

PARTICLE PHYSICS

STUDY GUIDE

MODULE - 17

PHYSICS AT ELMWOOD

PHYSICS 200

PARTICLE PHYSICS

PRE-REQUISITE: ELECTROMAGNETIC MODULE

(A) NEW CONCEPTS

Introduction; Graininess of light; (A brief recapitulation of the properties of light like interference); Relation between particle nature of light and interference; The photo-electric effect; Einstein's theory of photo-electric effect; Historical and scientific impact of Einstein's theory upon the status of physics; Particles of Light-photons; The mechanism of the photon; Particle like behaviour of radiation wave like behaviour of particles; De Broglie wavelength of particles; Dual nature of matter or wave-particle duality; Historical development of x-rays; Matter waves; Some results of relativity theory-relativistic mass; Derivation of $E = mc^2$. The Uncertainty Principle.

(B) EXTENDED TOPICS

1. Einstein and Modern Science.
2. Newtonian mechanics vs. Relativistic mechanics.
3. A Biographical Sketch of Albert Einstein.
4. Dual Nature of Matter.
5. Applications of Quantum Physics.
6. The Laser.
7. The Transistor.
8. Dual Nature of Light.
9. Solid State Physics.

(C) LABORATORY INVESTIGATIONS

1. Millikan's experiment for the measurement of the charge on an electron (if not previously done).

2. The photo-electric effect, experiment no. 43, PP Unit 5. A very important and highly enjoyable experiment. Full details in the PP unit 5 handbook (lab guide).

(D) AUDIO VISUAL

1. Films:

   (a) The Photo-electric effect (PSSC).

   (b) Matter Waves (PSSC).

   (c) Photons and Intereference of Photons (PSSC).

   (d) Frank Hertz experiment (PSSC).

   (e) The Strange Case of Cosmic Rays (Bell Labs).

(E) EXTENDED READING

(a) PSSC Science Study Series:

   1. Physics of T.V.
   2. The Neutron Story.
   3. Knowledge and Wonder.
   4. Accelerators.
   5. Thirty Years that Shook Physics.
   6. J.J. Thompson-Discoverer of the electron.
   7. Relativity and Commonsense.

(b) PP Reader No. 5 Articles:

   1. Failure and Success.
   2. Einstein.

3. The Clock Paradox.
4. Ideas and Theories.
5. Mr. Tompkins and Simultaneity.
6. Mathematics and Relativity.
7. Parable of the Surveyors.
8. Outside and insides of the Elevator.
9. Einstein and Some Civilized Discontents.
10. The New Landscape of Science.
11. The Evolution of the Physicist's Picture of Nature.
12. Dirac and Born.
13. I am the Whole World: Erwin Schrodinger.
14. The fundamental Idea of Wave Mechanics.
15. The Sea Captain's Box.
16. Space Travel: Problem's of Physics and Engg.
17. Looking for a new Law.

(F) COMPLETION TIME

Four to five weeks.

MODULE NO. 18

RADIOACTIVITY

STUDY GUIDE MODULE - 18

RADIOACTIVITY

PRE-REQUISITE: MODULE NO. 1

(A) NEW CONCEPTS

BASIC

Introduction-Events leading to Henry Becquerel's discovery of Radioactivity; Discovery of other radioactive elements-the work of the "Curies"; Three types of radiations and their properties including charge and mass; Radioactive transformations; Radioactive decay series; Decay Rate and half-life; Isotopes-natural and artificial, stable and unstable; Transformation Rules; Positive rays; Notation for Nuclides and nuclear reactions; Atomic masses.

OPTIONAL

Mathematics of Decay and the working of a Mass Spectrograph-separation of isotopes.

(B) EXTENDED TOPICS

1. Matter and Anti-Matter.
2. Radioisotopes and Agriculture.
3. Radioisotopes and Medicine.
4. Hazards of a Nuclear War.
5. Atomic-Energy-Use and Misuse.
6. Radiations and their Effect Upon Human Life.
7. Conservation Laws and Nuclear Reactions.
8. Accelerators-Machines of Human Progress.
9. Atomic Energy-Future Prospects.

10. Energy Crisis and Nuclear Power.

11. Energy from Fission and Fusion.

12. Nuclear Wastes-Their Effect Upon the Environment.

(C) LABORATORY INVESTIGATIONS

1. Experiment No. 45 on Random Events, PP Unit 6 Handbook. Any one or more of the following methods can be used:
   (a) Twenty sided dice.
   (b) Diffusion Cloud Chamber.
2. Experiment No. 46-Range of Alpha and Beta Particles. The experiment uses a Geiger Counter and a cloud chamber.
3. Experiment No. 47-Determining the half-life of Thorium. The experiment uses a Geiger Counter and other inexpensive equipment.
4. Experiment No. 48-Half-life II, PP Unit 6.

NOTE: Only one of the above mentioned experiments need to be carried out on half-life.

(D) AUDIO VISUAL

Films: Films dealing with almost any aspect of Radioactivity and atomic energy can be obtained free of charge from the U.S. Atomic Energy Commission, Washington, D. C. Other useful and freely available films are the following:

1. Basic Physics of an atomic bomb, from the U.S. Dept. of the Army.
2. Nuclear Reactors for Research, from North American Aviation Inc., 12214 Lakewood Blvd., Downey, Calif.
3. The Strange Case of Cosmic Rays, from Bell Telephone Labs.

Transparencies: From PP Unit 6 set of transparencies

1. Separation of Alpha, Beta and gamma rays.
2. Rutherford's Alpha-Particle Mousetrap.
3. Radioactive Disintegration Series.

(E) EXTENDED READING

The following articles are from PP Unit 6 Reader:

1. Nature of the Alpha Particle (PP Unit 6 article).
2. Rutherford (PP Unit 6 article).
3. The Privilege of being a Physicist.
4. One Scientist and His View of Science.
5. The Development of the Space-Time View of Science.
6. Physics and Mathematics.
7. Where do we go From Here?

The following articles are from The Physics Teacher:

1. Half-life Using Short-lived Radioisotopes, April, 68.
2. Elementary Particles, January, 64.
3. Cerenkov Radiation: Its origin, properties and applications, November, 63.
4. A simple experiment to illustrate radioactive decay, Half-life and time constant, May, 71.
5. Atomic Explosives-Solved and Unsolved Problems, May, 68.
6. The Meaning of the Conservation Laws, April, 71.
7. An inexpensive continuous Cloud Chamber, May 63.

PSSC Science Study Series:

1. Accelerators: Machines of nuclear Physics.
2. The Heart of the Atom-The Structure of the Atomic Nucleus.

Other References:

1. The Discovery of the Electron, Momentum Book, Van Nostrand Co.
2. Elementary Particles, Momentum Book, Van Nostrand Co., Pub.
3. Experiments with Radioactivity, National Science Teachers' Association, Washington, D.C. ($0.50).
4. Laboratory experiments with Radioisotopes (for high schools) U.S. Atomic Energy Commission, Washington, D.C. ($0.30).
5. Nuclear Research, one copy free from Information Div., Radiation Laboratory, Univ. of Calif., Berkley, Calif.
6. Atomic Radiation and Life, Penguin Books, Baltimore, Md.

The Following Articles from the Scientific American:

1. Anti-Matter, April, 1958.
2. The two-mile accelerator, November, 1961.
3. Radioactivity and Time, August, 1949.
4. Fusion Power, December 1957.
5. The age of elements in the solar system, November, 1960.
6. Reactor fuel elements, July, 1959.
7. The Synthetic elements I, April, 1950.
8. The Synthetic elements II, December, 1956.
9. The Synthetic elements III, April, 1963.
10. The Stellerator, October, 1958.

Other Free Reference Materials:

Each school can obtain a set of about 50 books dealing with the various aspects of atomic energy by writing to the U.S. Atomic Energy Commission, Washington, D.C. The series of books is entitled, "Understanding the Atom".

<u>The Following Articles are From The Science Teacher:</u>

1. Radiation Safety, December, 63.

2. Determination of Half-Life, December, 58.

3. Radiation Preservation of Foods and its Effect on Nutrients, March, 70.

4. A simple and inexpensive Geiger Counter, May, 59.

(F) COMPLETION TIME

Four to five weeks.

MODULE NO. 19

EXPLORING THE NUCLEUS

STUDY GUIDE MODULE - 19

PHYSICS AT ELMWOOD

PHYSICS 200

EXPLORING THE NUCLEUS

PRE-REQUISITE: MODULE ON RADIOACTIVITY

(A) NEW CONCEPTS

BASIS

Introduction-The problem of the structure of the atomic nucleus; brief recapitulation of the events leading to the discovery of the artificial transmutation of elements by Rutherford, and discovery of neutron by James Chadwick; Different theories about the structure of the nucleus-the proton-electron hypothesis and the proton neutron hypothesis; The neutrino; Need for particle accelerators-different types and their contribution to the advancement of science; Nuclear reactions-natural and artificial.

OPTIONAL

Conservation of energy in nuclear reactions; binding energy; Mass energy balance in nuclear reactions; Nuclear fission and nuclear fusion; Controlling chain reactions-energy released by nuclear fission. Plasmas; Fusion reactions in stars; strength of nuclear forces; Models of the nucleus-the liquid drop model and the shell model; Biological and medical applications of nuclear physics.

(B) EXTENDED READING

Much of the reference material under this heading has been mentioned in the module on radioactivity. The following are some of the additional articles from PP Unit 6 Reader, which are relevant to this module:

1. New World of Nuclear Power.
2. Models of the Nucleus.
3. Power from the Stars.
4. Success.
5. The Nuclear Energy Revolution.
6. A Report to the Secretary of War
7. Calling all Stars.
8. Tasks for a World Without War.
9. Some Personal Notes on the Search for the Neutron.
10. Antiprotons.
11. The tracks of Nuclear Particles.
12. The Spark Chamber.
13. The Evolution of the Cyclotron.
14. The Cyclotron as seen by .....
15. Cern.
16. Conservation Laws.
17. The Fall of Parity.
18. Can Time go Backward?
19. Particle Accelerators.

(C) EXTENDED TOPICS

Same as in the module on Radioactivity.

(D) AUDIO VISUAL

Same as in the last module, plus the following:

Film-loops: 1. Collison with an object of an unknown mass.

Transparencies: Binding energy curves (PP unit 6 set of transparencies.

Films: The Project Physics course has made only three films being given below, which specially deal with modern physics. Other than that, they recommend that the PSSC films be used wherever needed.

1. People and Particles.
2. The World of Enrico Fermi.
3. Synchrotron.

NOTE: These three films are available on a rental basis from Holt, Rinehart and Winston, the publishers of the PP course.

(E) COMPLETION TIME

Four to five weeks.

SOME FURTHER COMMENTS ABOUT THE MODULES

1. As explained at the beginning of this chapter, each module is a learning package, designed to be used by individuals, or small groups of students, working independently, or as a group.

2. The average module is designed to take approximately four weeks to be completed which means that the average completion time would vary from three to five weeks, depending upon the nature of the module, the teaching approach to be followed by the teacher concerned, and the level of the students.

3. In all, twenty modules are designed, and some of these can be dealt with independently of the others, or to put the same thing in different words, can be worked in almost any sequence. However, some modules are pre-requisites to the completion to the others.

4. Each module consists of a set of clearly worded objectives, containing all the information the student is possibly going to need in order for him to complete the module successfully.

5. Each module will encourage the student to work through the module at the rate he/she feels relevant to his/her ability.

6. The evaluation systems suggested should prove to be advantageous over the conventional grading systems, in that the point system for example, will enable each student to keep track of the progress he/she is making as he/she progresses through each module.

7. Each module would enable every physics teacher concerned to introduce his own individuality as far as teaching approach and teaching style are concerned, while at the same time enable him to improve the educational environment through greater encouragement, initiative and incentive.

8. In general, the basic framework has been laid, and the rules of the game specified. There seems to be more than enough freedom within each module, so that each teacher can chart out a study guide, keeping in mind the needs and requirements of his students, and the facilities available.

9. It is the author's earnest belief, that if a teacher takes the suggested approach outlined in this project seriously, and wants to make it work, there is ample opportunity for him to do so.

CONCLUSION

And now, to sum it all up, the author undertook to work on this project on the basis of his practical experiences within the physics classroom, and on the basis of his teaching in the summer institutes for teachers in the United States. No single physics course will work for any given situation. That is why in this MAP project, the best of everything has been combined and presented for the benefit of all concerned, at one place in the form of modules. The author sincerely believes that physics should be an enjoyable opportunity for each student, working as independently as possible, to discover and understand physical phenomena to the limit of his interest and ability. Towards this end, a workable approach has been presented, an approach that combines that right amounts of fun and independence with the right amounts of student responsibility and the contents of the subject matter. The subject matter has not been sacrificed. It is sincerely hoped, and the author has tested this to be the case, that the teachers concerned will find both the philosophy and the approach of the project and its wealth of multi-media learning materials ideally suited for their purpose.

Concerning progress and evaluation, only by completing the entire course with a high degree of proficiency could a student make an "A" grade, while only by failing to complete a very minimal assignment could a student fail.

The present approach seeks to combine some of the most successful elements of the traditional and individualized approaches. With the exception of a very few, highly gifted and motivated students, the class should be able to progress through the course together at a pace prescribed by the teacher. It is also to be hoped that this approach will work, no matter what system the school might be following-the traditional one year school, or the semester system.

Most probably, individual teachers will be able to improve upon the present approach so that it becomes even better compatible with our philosophy and goals to be satisfactory to all of us. But every instance we observe of a student's self-achievement and enjoyment of physics to us that we are on the right track.

MODULAR APPROACH TO PHYSICS

M A P

A PILOT PROJECT WITH A HUMANISTIC APPROACH

CHAPTER 5

EVALUATION AND RECOMMENDATIONS

EVALUATION AND RECOMMENDATIONS

In the preceeding chapters, the author has tried to present, what he considers to be a synthesis between the two major curriculum developments in high school physics, namely, the PSSC course and the more recently developed course - The Harvard Project Physics. In doing so, the author has also taken into account other various curriculum developments which has been carried out on a rather small scale, such as on a provincial basis or on an individual basis in certain schools in North America. Throughout the development of this pilot project, the humanistic approach to curriculum development was kept in mind, thereby incorporating a greater degree of flexibility both from the teacher's as well as the student's point of view. The project, as it stands now, should meet the needs and requirements of everyone concerned with the prevailing trends in physics education at the high school level. Some of these include declining trends in enrollment, the students loosing interest in the subject, and the need to present physics from a humanistic point of view by taking into account the needs and requirements of students with varying degrees of abilities and capabilities. The project has incorporated the multi-media system for stimulating better learning and should enable individual teachers to make a coherent selection within physics, depending upon their own teaching styles and the needs of their students, and the facilities available.

EVALUATION OF THE PILOT PROJECT

As has been mentioned earlier, the author has been teaching this pilot project and evaluating its effectiveness in his own high school throughout the period of development of this course. Changes and modifications were introduced wherever necessary. The following are some of the simple but easily understandable results which have given a tremendous amount of confidence and encouragement to the author regarding the effectiveness of the program.

(A) RESULTS OF A STUDENT QUESTIONNAIRE REGARDING OPINIONS - ABOUT PHYSICS:

The students in the three physics classes were asked to complete a questionnaire regarding their opinions about the MAP course. Since the author is also piloting the new PP course for the first time in the province, the students in this class were also handed out the same questionnaire. This questionnaire was obtained through the courtesy of Professor Fletcher Watson of the Graduate School of Education at Harvard University. In this questionnaire, there were twenty statements made by students who were taking or had taken a one year course in Project Physics. The results of this questionnaire were analysed and are given on the following page. While going over the results of the questionnaire, it should be borne in mind that the class taking the PP course is basically a low achievement class and is only handling the Canadian version of the U.S. edition of the PP course. The Canadian edition is a watered down version of the U.S. edition of the PP course. The other three classes handling the MAP project were in a way using a combination of the various courses such as the PSSC, PP, Physics by Genzer and Youngner and other curriculum development projects in physics, and as such were exposed to more physics with a higher mathematical content than the students using the Canadian edition of the PP course. When the results of the questionnaire are looked at with this perspective, it is quite evident that for the MAP program, the results are extremely encouraging. Whereas the author did not carry out a similar test last year, the enrollment figures for this year (1973-74) were compared to those of last year (1972-73), when the only course being taught in the school was the PSSC course. These enrollment figures lend further support to the fact that the MAP project is working out much better and is attracting the attention of a much higher percentage of students than last year.

Some other comments that must be made in order to clarify the results of the questionnaire are the following:

1. The students who were on the MAP project, were not really using any one particular text-book, although officially, each of them had either to sign up for the PSSC or the Physics by Genzer and Youngner text-book. Because of the study guide supplied to each student for each module, the students were

free to consult any other textbook they liked, as mentioned in the study guide, a sample of which has been given in the last chapter. In view of the way the MAP project is set up, the system of following just one textbook for the entire class defeats the very purpose of the entire project.

2. The following results from the questionnaire provide some insight into the effectiveness of the program and the approach it follows:

   (a) 80% of the students tested said they would recommend this course to their friends for next year.

   (b) 66% of the students tested said they disagreed with the statement that physics was one of the most difficult courses they had taken in the school.

   (c) Only 21% of the students said they disagreed with the statement that the course should not be changed too much.

   (d) 61% of the students tested said this course had made physics interesting to them, while 68% of the students agreed with the statement that this course could be handled by students who had little background in mathematics.

   (e) 88% of the students disagreed with the statement that they didn't have a good math background for this course.

should be borne in mind that the class taking the PP course is basically a low achievement class and is only handling the Canadian version of the U.S. edition of the PP course. The Canadian edition is a watered down version of the U.S. edition of the PP course. The other three classes handling the MAP project were in a way using a combination of the various courses such as the PSSC, PP, Physics by Genzer and Youngner and other curriculum development projects in physics, and as such were exposed to more physics with a higher mathematical content than the students using the Canadian edition of the PP course. When the results of the questionnaire are looked at with this perspective, it is quite evident that for the MAP program, the results are extremely encouraging. Whereas the author did not carry out a similar test last year, the enrollment figures for this year (1973-74) were compared to those of last year (1972-73), when the only course being taught in the school was the PSSC course. These enrollment figures lend further support to the fact that the MAP project is working out much better and is attracting the attention of a much higher percentage of students than last year.

Some other comments that must be made in order to clarify the results of the questionnaire are the following:

Table 2:

(A) PSSC Course

No. of students enrolled in PSSC 200 during 1972-73:	58
No. of students going on to PSSC 300 during 1973-74:	28
No. of drop-outs:	30
Percentage of drop-outs:	52%

(B) MAP Program

No. of students enrolled in Phy 200 (MAP) during 1973-74:	35
No. of students going on to Phy 300 (MAP) during 1974-75:	30
No. of drop-outs:	5
Percentage of drop-outs:	14.3%

(Out of these 5 drop-outs from the MAP program, 4 were actually recommended to switch on to the PP (Canadian Edition) class, so that only one student out of a total of 35 actually left physics.)

Comparison of Drop-out Rates

PSSC vs. MAP

Table 3

(A) MAP Program

No. of students enrolled in Phy 200 (MAP) during 1974-75:	45
No. of students enrolled in Phy 300 (MAP) during 1974-75:	30
Percentage increase of Phy 200 enrollment over 1973-74:	29%

(B) PP Course

No. of students enrolled in PP (Canadian) in 1973-74:	20
No. of students enrolled in PP (Canadian) in 1974-75:	30
Percentage increase:	50%
No. of students going on to PP (Canadian) 300 in 1974-75:	26

Comparison of Physics Enrollments

1. The students who were on the MAP project, were not really using any one particular textbook, although officially

   (f) 56% of the students said they agreed with the statement that this course was one of the most interesting courses they had taken in the high school.

The above statistics speak for themselves and for the effectiveness of the course and the approach i follows in trying to help them through such things as study guides and other components of the multimedia approach.

ENROLLMENT - COMPARISONS

The figures given in the tables on pages 186 and 187 further strengthen the author's belief that the MAP program is the course suited for a majority of the students graduating out of the high school.

SOME COMMENTS ABOUT THE ENROLLMENT FIGURES

A detailed analysis of the enrollment figures over the past two years and the number of students who have signed up for physics for next year, leads one to the following important conclusions:

1. The total no. of students enrolled in physics shows an increase of 75% over 1973-74.
2. The dropout rate in case of students taking the MAP program has gone down from a high of 52% in 1973-74 to a mere 14% in 1974-75.
3. For the first time in the history of the school, the students taking science 101 were contacted, and 20 students offered to enroll in physics, five of them in the MAP program and 15 in

Table 4

Second Term Results for 1972-73 and 1973-74

Course No.	Class Av. During		Pass %age		Math 200 Cl.Av.
	1972-73	1973-74	1972-73	1973-74	
Phy 300	60.3%	69.8%	80.2%	89.0%	
Phy 200	61.7%	70.8%	78.3%	90.0%	61.6%
PP 200	--	72.7%	--	100.0%	50.6%

Table 5

RESULTS OF A STUDENT QUESTIONNAIRE REGARDING OPINIONS ABOUT PHYSICS

Questionnaire supplied through the courtesy of Dr. Fletcher Watson of the Harvard Univ. Faculty of Education

NO.	STATEMENT	Agree		Disagree		Not sure/No opinion	
		PP	MAP	PP	MAP	PP	MAP
1.	Most of the labs were not that informative for the amount of time spent on them.	30	43	70	57	-	-
2.	Last year I was hesitant to take physics because so many people told me how tough it was.	45	60	55	40	-	-
3.	I think this physics course is designed in such a way that even those who have little background in math can gain much from the course.	90	68	10	29	-	3
4.	This course has made physics interesting to me.	35	61	30	36	35	3
5.	The text is well written.	85	NA	10	NA	5	NA
6.	I don't think I have a good enough math background for this class.	5	12	90	88	5	0
7.	The course has not been the drag I expected physics to be.	50	68	40	23	10	9
8.	The labs are fun.	40	50	60	41	-	9
9.	I think learning about the men and women who made physics grow helped to make the course more interesting.	55	42	35	34	10	24
10.	This physics course was one of the most interesting courses I have taken in high school.	35	56	55	41	10	3
11.	I would recommend this physics course to my friends.	100	80	0	20	-	0
12.	The book was really enjoyable to read.	45	NA	45	NA	10	21
13.	Primarily as a result of this physics course, I plan to take another physics course in college.	20	20	55	40	25	40
14.	Our class finished the text.	NA	NA	NA	NA	NA	NA
15.	I plan to major in physics in college.	10	16	95	66	0	6
16.	Physics is one of the most difficult courses I have taken in high school.	5	28	90	80	5	6
17.	No matter how you look at it, physics has to be a difficult course.	5	14	90	80	5	6
18.	I guess physics is all right if you like that sort of thing....to me it's just filling one of my pre-college requirements.	50	26	45	68	5	8
19.	I hope they don't change the course too much.	85	55	10	21	5	24
20.	In college, I plan to major in science, but not in phy.	40	20	15	32	45	48

the PP course. It must be pointed out here that the students studying the PP course were also being exposed to the same basic approach as the students in the MAP program, the only difference being that these students were only using the PP texts and handbooks (lab manuals). What all this means is that the general atmosphere of horror about physics seems to be vanishing and physics no longer is being looked upon as a dreadful subject meant only for the elite of the student population.

PERFORMANCE LEVELS OF STUDENTS

Statistics calculated on the basis of the second term marks obtained by students in the various classes provide some thought provoking results. These are being summarized on page 189 and are being compared with second term results of last year.

RECOMMENDATIONS

On the basis of all that has been said above and in the last few chapters, the author wishes to make the following recommendations regarding the newly developed pilot program, called 'MAP' or the 'MODULAR APPROACH TO PHYSICS', and the Project Physics (PP) course:

1. The first and foremost recommendation that the author would like to make is that the traditional approach of one textbook for every student be given up, since it is no longer conducive to the modern humanistic approach to curriculum development. This particularly holds true about the PSSC text, since most of the students find its reading level beyond their reach. Also, the choice of the

textbook be left at the discretion of the classroom teacher who should be entrusted with the responsibility of choosing whichever textbook he/she likes best, taking into consideration the needs of his/her students and his/her own teaching style. What should be laid down by the Department of Education is the course content, and that's all. The teaching approach, the system of evaluation and the choice of the textbook should all be left at the discretion of the teacher concerned. The Modular approach suggested by the author should go a long way in meeting the needs and requirements of both the teachers and the students concerned. This approach, it is sincerely hoped, would lend itself quite suitably to virtually any kind of teaching situation, enable the teacher to take into account the varying degrees of student abilities to cope with the subject and also enable the teacher to introduce his own teaching style, if he/she wishes to do so. In short, the MAP program is quite flexible in meeting the needs of students and, as pointed out above, would help a great deal towards arresting the declining trends in physics enrollments across the province.

2. If we are really interested in offering physics to a larger percentage of the high school population, the author, on the basis of his personal experience over the past four years recommends that together with the MAP program, if a school can afford, the PP (Canadian Version) be also introduced. This would help the bottom of the ladder students with a chance to study physics.

3. The author further recommends that a copy of the entire MAP program be supplied to each physics teacher in the province by the Provincial Department of Education.

4. It is also recommended that the Department of Education, in cooperation with the Faculty of Education, University of Manitoba, initiate arrangements to offer the Project Physics course to enable the physics teachers in this province get acquainted with the approach and philosophy behind this course. This will go a long way in helping teachers to adapt to the MAP program much more effectively.

5. Each high school in the province offering physics courses should be encouraged to set up a resource center for physics. This resource center should enable students to have easy access to the reference materials in the nature of books on physics (A comprehensive list of selected references for this purpose is being given in appendix 2 at the end of the last chapter), facilities for viewing filmloops etc. At least five copies of the printed materials of the Project Physics course, including text and handbooks and readers should form a part of such a resource center. In most cases, a separate resource center for physics might not be necessary, and facilities might already exist or accommodation possible within the existing facilities.

APPENDIX - 1

A LIST OF SCIENTIFIC EQUIPMENT MANUFACTURING FIRMS

Besides the regular and usual scientific equipment manufacturing companies which are familiar to most of the teachers, the ones being mentioned below should be contacted for more modern physics equipment:

1. Metrologic Instruments, Inc.,
   143 Harding Avenue,
   Bell-mawr, N.J. 08030

2. Klinger Scientific Apparatus Corporation
   83 - 45 Parsons Blvd.,
   Jamaica, N.Y. 11432
   (For Blackboard Optics Set)

3. Griffin & George Limited
   3650 Weston Road,
   Weston, Ontario.

4. Pasco Scientific,
   1933 Republic Avenue
   San Leandro, Calif. 94577

5. Pickett Industries,
   P.O. Box 1515
   Santa Barbara, California 93102

6. Ealing Scientific Limited
   9649 Cote de Liesse,
   Dorval 760, Quebec.
   (For film-loops and film-loop projectors)

7. Thornton Associates, Inc.,
   87 Beaver Street
   Waltham, Mass. 02154.
   (highly recommended)

APPENDIX - 2

A Suggested List of Books - Reference Purposes

(A) PSSC Science Study Series - (Paperback)

1. Relativity and Common Sense
2. Sir Isaac Newton
3. The Universe at Large
4. The Watershed - A Biography of Kepler
5. Knowledge and Wonder
6. Mathematical Aspects of Physics
7. Sound Waves and Light Waves
8. Thirty Years That Shook Physics
9. The Birth of a New Physics
10. Gravity
11. The Echoes of Bats and Men
12. How Old is the Earth
13. Crystals and Crystal Graving
14. Near Zero
15. Weather on Planets
16. The Restless Atom
17. Michelsan and the Speed of Light
18. The Neutron Story
19. Pasteur and Modern Science
20. Water - The Mirror of Science
21. Heat Engines
22. Accelerators - Machines of Nuclear Physics
23. Lady Luck

24. Count Rumford
25. Waves and the Ear
26. Waves and Beaches
27. Horns, Strings and Harmony
28. Physics of Television
29. Electrostatics
30. Sir J. J. Thompson
31. Latent Image
32. Perpetual Motion
33. Magnets
34. The Unclean Sky
35. The Edge of Space
36. Shape and Flow
37. The Heart of the Atom
38. Quantum Electronics
39. Electrons and Waves
40. Waves and Messages
41. The Tides

(B) <u>Other Books</u> (Westinghouse Search Books - Library)

1. Seven States of Matter
2. Science of Science
3. Science by Degrees
4. Electrons on the Move
5. Math and Aftermath
6. Energy does Matter
7. Crystals - Perfect and Imperfect

(C) Sources for Article Reviews

1. Project Physics Readers, one to six
2. Scientific American Reprints
3. Scientific American Magazines

(D) Van Nostrand Momentum Books

1. Elementary Particles
2. Radio exploration of the Planetary System
3. The Discovery of Electron
4. Waves and Oscillations
5. Crystals and Light
6. Temperatives - very low and very high
7. Polarized Light
8. Structure of Atomic Nuclei
9. An Introduction to the Special Theory of Relativity
10. Infra-red Radiation
11. Radioactivity and Its Measurement
12. Plasmas

(E) Other Books

1. One, Two, Three...Infinity by George Garvow
2. Mr. Tompkins in Wonderland by George Garvow
3. The Birth of the Sun by George Garvow
4. Music of the Spheres
5. Order and Chaos (Room 5)
6. Relativity for the Beginning Reader
7. Atoms in the Family

8. Crime of Galelio
9. The electron
10. Inside the Atom
11. The Universe and Dr. Einstein
12. Physics and Man
13. Men who mastered the Atom
14. Space Science and You
15. Biography of the Earth
16. The Nature of the Universe
17. Watchers of the Skies
18. The Creation of the Universe
19. The Universe of Galelio and Newton
20. What is Light
21. No More War
22. Exploring the Universe
23. The Origins of Modern Science
24. Frontiers of Science
25. Science and Serendipity
26. The Explosion of Science
27. The Moon and the Planets

(F) Biographies

1. Newton
2. Galelio
3. Einstein
4. Copernicus
5. Kepler
6. Faraday, Maxwell
7. Enrico Fermi
8. Max Planck
9. Tycho Brahe
10. Rutherford
11. Michelson
12. Millikan

(G) Time Life Books

1. The Universe
2. Light and Vision
3. Energy
4. Matter
5. Machines
6. Time
7. Sound and Hearing

(H) Holt Science Series

1. The Physics of Space
2. Meterological Satellites
3. Communications in Space
4. A History of Space Flight
5. Manned Space Flight
6. Thurst into Space
7. The Images of Space
8. Our Space Environment
9. The Math of Space Exploration
10. Unmanned Space Flight

(I) Selected References - High School Physics Texts

1. PSSC Physics
2. Physics for High School by Kelly and Miner
3. Physics by Genzer and Youngner
4. Project Physics
5. Physics - A Human Endeavor
6. Concepts in Physics

7. Physics by Taffel

8. Physics by Stollberg and Hill

9. Modern Physics

(J) Advanced Physics Texts

10. A Contemporary View of Physics

11. Development of the Concepts of Physics

12. Physics for the Enquiring Mind

13. Physics by Resmick and Halliday

14. Physics by Freeman

15. Physics by Lehrman and Swartz

(K) Longman Physics Topics

1. Ideas and Discoveries in Physics

2. Waves or Particles

3. Planetary Astronomy

4. Forces

5. Using Light

6. Mass in Motion

7. Radioactivity

8. Waves

9. Heat

(L) Understanding the Atom (U.S.A.E. Commission)

Selected Textbooks

Accelerators

Animals in Atomic Research

Atomic Fuel

Selected Texbooks-Con't:

Atomic Power Safety

Atoms at the Science Fair

Atoms in Agriculture

Atoms, Nature, and Man

Books on Atomic Energy for Adults and Children

Careers in Atomic Energy

Computers

Controlled Nuclear Fusion

Cryogenics, The Uncommon Cold

Direct Conversion of Energy

Fallout From Nuclear Tests

Food Preservation by Irradiation

Genetic Effects of Radiation

Index to the UAS Series

Lasers

Microstructure of Matter

Neutron Activation Analysis

Nondestructive Testing

Nuclear Clocks

Nuclear Energy for Desalting

Nuclear Power and Merchant Shipping

Nuclear Propulsion for Space

Nuclear Reactors

Nuclear Terms, A Brief Glossary

Our Atomic World

<u>Selected Textbooks-Con't:</u>

Plowshare

Plutonium

Power from Radioisotopes

Power Reactors in Small Packages

Radioactive Wastes

Radioisotopes and Life Processes

Radioisotopes in Industry

Radioisotopes in Medicine

Rare Earths

Research Reactors

SNAP, Nuclear Space Reactors

Sources of Nuclear Fuel

Space Radiation

Spectroscopy

Synthetic Transuranium Elements

The Atom and the Ocean

The Chemistry of the Noble Gases

The Elusive Neutrino

The First Reactor

The Natural Radiation Environment

Whole Body Counters

Your Body and Radiation

(M) <u>Titles of Project Physics Supplementary Units</u>*

1. Accelerators and Reactors
2. Special Relativity

Titles of Project Physics Supplementary Units*-Con't

3. Thermal Motion

4. Astronautics and Space Physics

5. Particle Physics

6. Discovery in the Physical Sciences

7. Biophysics

8. Cosmology

9. The Physics of Everyday optics

10. Diffraction: Observing the world through small openings

11. Chemistry and Physics

12. Radioisotopes and their Applications

13. Social Consequences of Scientific Technology

14. Physics and Engineering

15. The Physics of Transportation

16. The Physics of Music

17. The Physics of Crystals

18. Physics and Electronics

19. Physics and Sports

20. Science and Literature

21. The Eye

22. The Ear

23. Physics for the Airplane Passenger

* Available from Holt Rinehart

APPENDIX - 3

LIST OF PUBLISHERS TO BE CONTACTED FOR PROJECT PHYSICS MATERIALS

Holt, Rinehart and Winston, 55 Horner Avenue, Toronto, Ontario, are the sole printers and distributors of the Project Physics printed materials. The PP printed materials are available either as separate units (six) or as one textbook (all the six text-units in one) and one handbook (all the six handbook units in one). The first alternative would certainly found to be more satisfactory, since the students would not have to carry all the six units at a time when they might only need one. As mentioned earlier, a Canadian version of the U.S. edition of the PP course, titled, 'Physics - A Human Endeavour' has also appeared in the market and is also published by the same publishers. The later, of course, is a watered down version of the U.S. edition, and the author's view is that teachers should go in for this course only if they are offering a second physics course as a terminal course to those who want to study physics, but do not want to get into the existing physics course/courses for one reason or another. The author has found this to be a workable approach - that of offering the MAP program in place of the PSSC or any of the others being taught in the province today, and the Canadian version of the PP course for the bottom of the ladder students. The result has been, as mentioned previously, a 75% increase in physics enrollments over a one year period.

Holt, Rinehart and Winston are also the distributors for the laboratory equipment for the PP course as well as the transparencies and the filmloops.

APPENDIX - 4

PROJECT PHYSICS TEACHER BRIEFING FILMS

Twenty-one teacher briefing films have been produced to assist teachers. They are in the form of 16mm sound films for projectors and video tapes for TV use. These films deal with the management of equipment as well as with methods and styles of teaching Project Physics. However, the briefings are not intended to take the place of teacher training institutes.

Electron Beam Tube

Experiments with Microwaves

Film Loop Techniques I

Film Loop Techniques II

Half-Life Experiments

Informal Class Activities

Measure of Elementary Charge

Naked-Eye Astronomy

Orbit Plotting

Photoelectric Effect

Polaroid LandPhotography, Part I

Polaroid Land Photography, Part II

Setting up the Current Balance

Working with Current Balance

Teaching about Physics and Society

Teaching Style I

Teaching Style II

Teaching Sytle III

PROJECT PHYSICS TEACHER BRIEFING FILMS-Con't

Using the Oscilliscope

Waves

Waves Modulated and Communication

These films may be purchased or rented from Holt, Rinehart and Winston, Inc., 383 Madison Avenue, New York, N.Y. 10017 or from National Instructional Television Center, Box A, Bloomington, Indiana 47401.

BIBLIOGRAPHY

B I B L I O G R A P H Y

(A) BOOKS:

1. Manning, Duane, Toward a Humanistic Curriculum, Harper and Row New York, 1971.
2. Collette, Alfred T., Science Teaching in the Secondary School. Allyn and Bacon, Inc., Boston, 1973.
3. Alexander, William M., The Changing High School Curriculum, Readings, Holt, Rinehart and Winston, Inc., 1972.
4. Bent, Rudyard K., Secondary School Curriculum, D.C. Heath & Co., Mass., 1969.
5. Association for Supervision and Curriculum Development, National Education Association, Humanizing the Secondary School, Washington, D. C., 1969.
6. Wilson, Craig L., The Open Access Curriculum, Allyn and Bacon, Inc., 1972.

TEXTBOOKS

1. PSSC Physics, D.C. Heath and Co., 1965.
2. Holton, Rutherford and Watson, Harvard Project Physics, Holt Rinehart and Winston, New York, 1970.

(C) REPORTS

1. The Secondary School, Report of the Core Committee on the Reorganization of the Secondary School, Department of Education, Province of Manitoba, 1973.

(C) REPORTS-Con't

2. Welch, Wayne W., Review of Research, Development and Progress of Harvard Project Physics, Center for Science Education. Columbus, Ohio, December, 1971, Eric Cat. No. ED - 059 887.

3. Flint, William, Project Physics Course, Modularized, Huxley College of Environmental Studies, West Washington State College, Bellingham, Washington, October 1971. Eric Cat. No. ED - 059 901.

4. New York State Department of Education, Physics-A Syllabus for Secondary Schools, 1967. Eric Cat. No. ED - 055 885.

5. Payne, John J., Physics Just For Fun, Plano High School, Plano, Texas, Feb. 1971. Eric Cat. No. ED - 055 837.

6. Alexander, William M., Curriculum Planning As It Should Be, Eric Cat. No. ED - 061 585, An address presented at an ASCD Conference on "The School of the Future', Chicago, Ill. 1971.

7. Yegge, John F., The Decision Making Process in the Adoption of a New Physics Course in American High Schools', Eric Cat. No. ED -052 961.

8. Development and Implementation of a New Type Program of Secondary School Physics, Eric Cat. No. ED - 042 657.

(D) HARVARD PROJECT PHYSICS MATERIALS, supplied by courtsey of Dr. Fletcher G. Watson, Professor in the School of Education at Harvard University. The following materials were consulted in the preparation of this paper:

(D) HARVARD PROJECT PHYSICS MATERIALS-Con't

1. Harvard Project Physics Newsletters, Nos. 1 to 10.
2. The Physics Teacher-Special Report on Harvard Project Physics, May 1967.
3. Evaluation of Harvard Project Physics Course-Interim Report, Remarks delivered by A. Ahlgren, AAPT, Feb. 3, 1969.
4. About the Project Physics Course, Introduction to The Teacher Resource Book.
5. The Course: Harvard Project Physics, Objectives and Materials.