DOCUMENT RESUME

ED 029 775 SE 004 285

By-Green, Ben A., Jr.; And Others
Preparing High School Physics Teachers.
Commission on Coll. Physics, College Park, Md.
Pub Date Jan 68
Note-25p.
EDRS Price MF-$0.25 HC-$1.35
Descriptors-*Conference Reports, Educational Trends, *Physics, *Secondary School Science, *Teacher Education, Teacher Qualifications, Teacher Recruitment, Teacher Supply and Demand, Undergraduate Study

Reported are (1) the status of preparation of physics teachers, and (2) recommendations for improving programs preparing physics teachers. The seriously declining high school physics enrollments are attributed, in part, to the shortage, or absence, of competent teachers. The effect this might have on the future supply of physicists is a major concern. A 1966 survey revealed that (1) well-known, high prestige college physics departments rarely had many courses to meet the needs of prospective high school physics teachers, (2) these departments typically graduate few physics teachers, and (3) less than 10 of the colleges surveyed graduated annually more than five physics teachers having a minimum of 18 semester hours of physics. Recommendations for improving high school physics teacher preparation programs include (1) preparing the physics teachers in at least one other area, (2) providing some courses other than the research-oriented bachelor's degree program, (3) planning the sequence of physics courses to recruit and accommodate students, (4) providing instructional styles that are compatible with high school methods of presentation, (5) including a course in the history and philosophy of physics, and (6) providing courses for inservice teachers. (DH)

COMMISSION ON COLLEGE PHYSICS

Preparing High School Physics Teachers

Preparing High School Physics Teachers

Report of the

Panel on the Preparation of Physics Teachers

of the

Commission on College Physics

Department of Physics and Astronomy

University of Maryland

4321 Hartwick Road

College Park, Maryland 20740

Contents

The Commission, The Panel, And The Workshop

The Commission on College Physics was established in 1960 to coordinate a national program to improve the teaching of physics at the college level. While much of its effort has gone into programs aimed at developing the professional physicist, the Commission has, from its beginning, recognized the profession's responsibility for and the importance of training high school teachers of physics.[1] The recommendation from the Second Ann Arbor Conference on Curricula for Undergraduate Majors in Physics[2] for the establishment of curricular routes other than that one which leads to physics graduate work was motivated in part by a desire to provide more pertinent coursework for the prospective high school teacher.

The Panel on the Preparation of Physics Teachers (PPPT) was established by the Commission in May 1966 to advise the CCP on present practice in teacher preparation and to recommend programs for its improvement. The Panel has chosen to concentrate initially on the preparation of high school teachers of physics because of the seriousness of the manpower problem there, the large number of students involved and the importance of the influence of the high school experience in physics on the college student.

[1] For a complete review of CCP activities see the 1964-66 Progress Report published as Part II, *American Journal of Physics, 34* (1966). Appendix II of that report contains a brief historical summary.

[2] *American Journal of Physics, 31,* 328 (1963). Reprints are available from the CCP office.

The PPPT sponsored a Workshop at the University of Minnesota, 5-9 June 1967, to develop a plan of action which would encourage college and university departments of physics to accept increased responsibility for establishing realistic academic programs for prospective high school teachers and for the recruiting of students into these programs.

The present report is essentially the report of the Minnesota Workshop and includes some of the statistical information which underlines the seriousness of the high school teacher problem. Additional copies of this report may be obtained from the CCP office.

* * * * *

ACKNOWLEDGEMENTS

Participants in the Minnesota Workshop greatly appreciate the efficient help of Miss Marlene Roeder of the CCP office and Mrs. Ruth Boutelle of the MINNEMAST project at the University of Minnesota.

Special thanks are due to Jim Werntz and Peter Roll who handled the local arrangements in Minnesota and to Morton Hamermesh who, on behalf of the School of Physics of the University, made its facilities available to us.

This report was written largely by Ben A. Green, Jr., Commission Staff Physicist, with the help of John M. Fowler, Director of the Commission, and Barbara Z. Bluestone and Rosemary Wolfe of the Commission staff.

January 1968

I. Introduction

In 1964 the National Academy of Sciences appointed a committee of distinguished physicists to survey the state of physics research and education in the United States. The Physics Survey Committee (informally known as the Pake Committee) reported [1] favorably on the state of physics research although it expressed some concern over means of paying the cost. It was less optimistic over the state of physics beyond the research laboratory.

According to the Committee, the physics profession faced at least two major problems with serious consequences for the future: (1) a shortage of physicists and (2) a failure to communicate with the general public. After estimating the future demand for physicists, the Committee concluded that physicists were in critically short supply in each major category of employment.[2] And with regard to communication: "Despite the intense interactions between physics and society, the understanding of the aims and content of physics by the public is generally very poor."[3]

These unpleasant facts are widely recognized by the physics community. Less familiar may be a further difficulty noted by the Committee:

> **A severe educational crisis for physics appears to be in the making in our high schools, where the fraction of students having a course in physics—never large in the past—has been seriously declining. A major cause for the decline . . . is the shortage, or even absence, of competent physics teachers in many secondary school systems.**[4]

It is the belief of the Commission on College Physics that this crisis is now upon us and, furthermore, that this shortage of competent high school teachers is itself a major cause of both the shortage of physicists and the lack of public understanding of physics. There are many other causes, to be sure: the need for better high school courses, better texts and equipment, and far more and better college-level physics courses for the students who do not have a professional need for physics. But the teacher himself is the most important element in the instructional process. And it is the high school teacher, who, of all physics teachers, sees the most students and sees them at an age when they are planning their careers. Unfortunately, of all high school teachers of the sciences, the physics teacher is the most likely to be poorly prepared. The statistics are told in the next chapter of this report.

[1] National Academy of Sciences, *Physics: Survey and Outlook* (Washington, D.C., 1966) p. 23.

[2] *Ibid.*, p. 31.

[3] *Ibid.*, p. 112.

[4] *Ibid.*, p. 30.

At its December 1967 meeting the Commission approved the following statement:

> **We believe that the shortage of qualified high school physics teachers is one of the most pressing problems facing American physics today in that its solution is central to the future vitality of our profession.**

The immediate urgency of the problem is increased by the four-year time lag between the institution of programs and the production of teachers and the even greater time before the appearance in the colleges of students trained by these teachers.

One of the early acts of the Commission's Panel on the Preparation of Physics Teachers[5] was to survey the state of high school teacher preparation programs in the colleges and universities. This informal survey showed that teacher preparation was not an important activity in most prominent physics departments, and that some of the small teachers colleges produced larger numbers of physics teachers than the large state universities. Some physics departments were too little concerned to keep records on the teachers they had produced.

That the teachers colleges are carrying the burden of the preparation of physics teachers is perhaps not surprising: the teachers colleges were founded for just the purpose of preparing teachers. The Panel feels, however, that the present problem for physics cannot be met by the teachers colleges alone. The concentration of resources and of students in the large universities gives them a share of this responsibility. Furthermore, in the other sciences the universities have already accepted this responsibility: in mathematics, biology, chemistry, etc. more high school teachers are prepared in the universities than in any other type of institution. It is only physics which lags behind.

It is the belief of the Panel that when the seriousness of the high school teacher situation is fully realized within the academic physics community, physicists will respond to the need for action.

What action to take was the concern of the Workshop, held 5-9 June 1967 at the University of Minnesota and attended by physicists, high school teachers and science educators.[6]

Obviously more teacher preparation programs must be established. But many questions arise: What does a high school physics teacher need to know, and what is a realistic curriculum? Where can one find students

[5] Appendix B lists the Panel members.

[6] Appendix A lists the participants in the Workshop.

for these programs? This report contains some answers suggested by Workshop participants.

The Commission on College Physics is publishing this report to call attention to the problem and these suggestions for its solution. It wishes to encourage physics departments to make serious commitments to the preparation of high school teachers of physics, and is prepared to assist the establishment of such programs. The Commission solicits inquiry from interested departments or individual physicists.

II. A Look At The Problem

Before discussing the extent of the teacher shortage, let us consider whether high school physics should not simply be abandoned, as is sometimes suggested. However attractive a solution this may seem, there is good reason to reject it.

As American education is now structured, the high school physics course is the most important single element both in recruiting new generations of physicists and in forming the public's impression of physics. Of the approximately 2.5 million high school students who graduate each year, about 0.5 million take high school physics. College introductory physics enrolls only about 0.2 million, most of whom have already had high school physics. Thus initial exposure to serious physics usually comes in high school.

Early exposure to physics is vital to the recruitment of new physicists. Of the recipients of physics bachelor's degrees in 1966, 94 percent took physics in high school. Whether their presence in the high school course generates an interest in physics or is merely evidence of a prior interest in it, only those who develop this early interest in science go on to serious study during their later years.

There is reason to worry about the number of students preparing to become physicists. The number of baccalaureate degree recipients in physics decreased in absolute number from 1964 to 1965 and even more so from 1965 to 1966, while in all other major sciences and in engineering the number went up (see Table I and Figure 1). The percentage of entering male freshmen who eventually earn a degree in physics decreased from 1.21 in 1962 to 0.85 in 1966 (Table II). If this trend continues, the number of B.S. degree holders available to enter our graduate schools and industrial research positions will drop alarmingly by 1970. Decreases in graduate enrollments were already being felt before the elimination of selective service deferments for physics graduate students in 1968 (still in doubt at this writing).

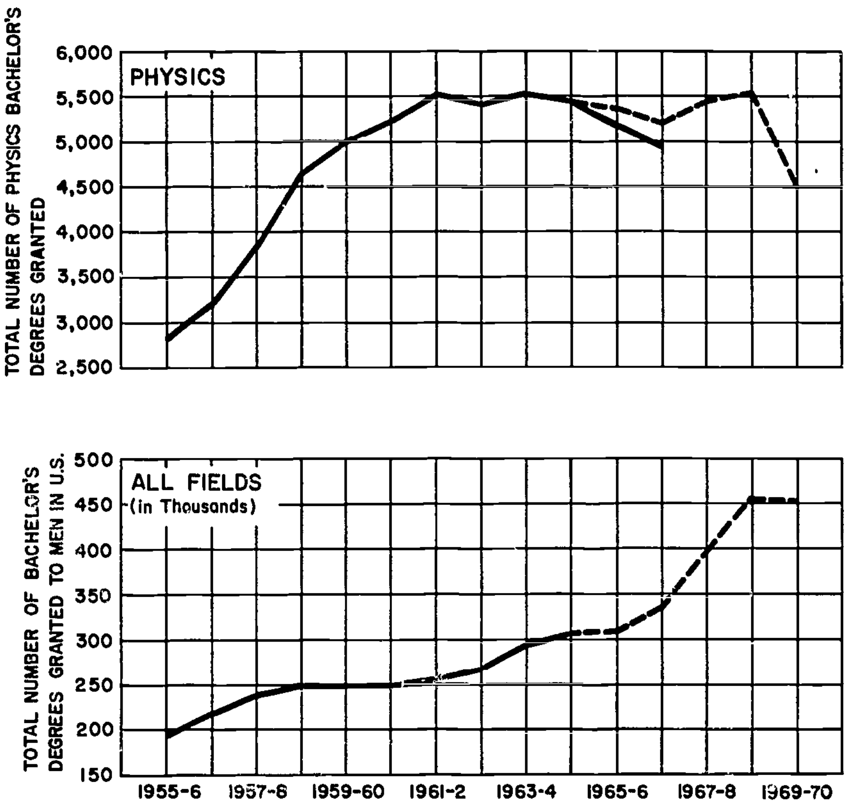


Figure 1. Trend in Bachelor's Degrees Granted. (From Physics Manpower 1966, A.I.P. Publication No. R-196, p. 39; A.I.P. Annual Survey of Enrollments and Degrees; and A.I.P. Annual Survey of Bachelor's Degree Recipients.) The dashed lines are projections from 1965 based on U.S. Office of Education statistics.

Alarm over the decline in the number of students preparing to become physicists should not be the only—nor perhaps even the major—reason to want to improve high school physics teaching. Our failure to communicate with the general public, the second problem pointed out by the Pake Committee, must be attacked at the high school level. Half of the high school graduates in the country get no further formal education. They will as citizens live in a society increasingly based on technology; they will take part in decisions affected by the discoveries of science; and

TABLE I

Trend in Bachelor's Degrees Granted to Men

Academic Year	*Total (Male)*	*Physics*	*Chemistry*	*Math & Stat.*	*Engineering*
1960-61	254,000	5,293	6,096	9,694	35,732
1961-62	260,000	5,622	6,371	10,355	34,610
1962-63	273,000	5,452	7,054	11,163	33,328
1963-64	298,000	5,611	7,805	12,682	35,067
1964-65	314,000	5,517	8,111	13,132	36,658
1965-66	315,000*	5,037			
1969-70	451,000*	4,500*			

* Projected

Sources: AIP Physics Manpower 1966. Pub. No. R-196. AIP Report R-151.4.

Note: Bachelor's degrees granted to women in physics, chemistry, mathematics and engineering are approximately 4%, 20%, 32%, and 0.5% of the total number of bachelor's degrees granted in those fields.

TABLE II

Percent of Male Freshmen Receiving Bachelor's Degrees in Physics Four Years Later

Graduating Class	*Physics Degrees % of Male Freshmen*
1962	1.21
1963	1.12
1964	1.04
1965	0.93
1966	0.85
1970 (projected)	0.57

Sources: AIP Physics Manpower 1966. Pub. No. R-196. p. 30 & 38.

AIP Report R-151.4.

they will make decisions governing the support of science, even if only through the ballot box. Their ignorance of the purposes of physics will further widen the gap between the practicing physicist and the society which supports him.

The college course for the nonprofessional should play a major role in developing an appreciation of physics in the college student (who will be, for the most part, the decision maker in society), but the student discouraged in high school is difficult to recapture in college.

Let us now return to the teacher situation. Most of our present high school physics teachers are unprepared to teach physics. The data are shown in Table III. Although the survey on which these figures are based was made in 1961, there is no evidence that major changes have occurred since then. Note that two-thirds of physics classes are taught by teachers having less than 18 semester-hour credits in physics and that physics fares worse by far than any of the other sciences listed.[1]

The critical factor is the low rate of supply of well-prepared new teachers. In 1966, 505 college seniors were expected to graduate certified to teach high school physics; 336 of these were expected to enter the teaching profession. The estimated demand for beginning physics teachers from among college graduates in 1966 was 572.[2] This shortage has led the National Education Association to designate physics as a "critical" subject area.

The demand quoted above includes only those positions for which it is expected that the teacher will devote over half of his time to physics. However, 81 percent of the 17,000 teachers who offer at least one section of physics teach *less* than half-time in physics. The demand for new "part-time" physics teachers can be estimated from the fact that about 10 percent of all secondary school teachers in 1966 were beginning teachers; if this percentage holds for physics, about *1700 beginning teachers each year* will be required to teach at least one section of physics. It is our continuing failure to provide anything like enough trained high school physics teachers that causes high schools to draft others for the job and leads to the deplorable percentages of Table III.

What are academic physics departments doing to remedy this situation? For the most part, very little. The 1966 PPPT survey revealed that:

TABLE III

Estimated Percentage of High School Classes Taught by Teachers Having Given Numbers of College Credits in Subject*

Subject	*0-8 Credits (sem. hrs.)*	*9-17 Credits (sem. hrs.)*	*18-29 Credits (sem. hrs.)*	*30+ Credits (sem. hrs.)*
Biology	8	13	22	57
Chemistry	14	20	32	34
Physics	23	43	20	14
Math. (9-12)	11	12	32	45

Source: NSF Secondary School Science and Mathematics Teachers, Characteristics and Service Loads. (NSF 63-10)

* For example, 43 percent of physics classes have teachers with 9-17 credits in physics.

This study is based on a survey of a stratified random sample (N=3012) of high school science teachers. Reporting the data by numbers of classes rather than numbers of teachers allows for the fact that better-prepared teachers are generally to be found where more physics sections are to be taught. The qualification "Estimated" is required by the use of adjustment factors to convert from numbers of teachers to numbers of classes. The results in terms of numbers of teachers actually do not differ greatly from those in terms of numbers of classes.

1. Well-known, high-prestige departments rarely have programs specifically tailored to the needs of the prospective high school physics teacher. They recommend the regular physics major program.
2. These same departments typically graduate two or three teachers *every five years.*
3. Less than ten of the schools surveyed graduate more than five physics teachers per year (having at least 18 semester-hours in physics).

There do exist a few moderate-sized schools with good programs (see section V of this Report) which graduate more than ten physics teachers per year. In these schools teacher preparation for secondary schools is regarded as an important function of the physics department, and money, space and faculty time are devoted to the task.

It is tempting to argue that the proper place to train physics teachers for high schools is in the teachers colleges which make this task their specialty. However, the teachers colleges are already the major producers of these teachers, and their output is not sufficient. In the other sciences the large majority of high school teachers do not come from teachers colleges. Of the science teachers responding to the survey from which Table III was taken, 31 percent received their bachelor's degrees from universities, 39 percent from liberal arts colleges, and only 29 percent from teachers colleges. (Since only 12 percent of these teachers taught any physics, the data represent mainly the situation in chemistry, biology, and mathematics.)

Why is it that the large physics departments with their relatively rich resources have ignored this re-

[1] It is quickly granted that number of credits is less than a perfect measure of fitness to teach physics, that there are excellent teachers of physics who have had only one course or even none in their subject, and that sixty hours in physics may leave one a poor teacher. But by and large one untrained in a field will not teach it well, and eighteen semester hours is not too high a threshold to set for adequate understanding of such a complex discipline as physics.

[2] These data are all from Research Report 1966—R-16, National Education Association, Washington, D.C.

sponsibility? For one thing, many university physicists do not know about the current crisis. But more important, they are under intense pressure to do research and to teach the graduate and undergraduate courses of the major program.

Research has traditionally held highest priority for the university physicist; the great contributions physics has made to the growth of our society attest to the correctness of this view. The rewards of success in research to the physicist, his department, and his institution have been so great and so immediate, however, that other endeavors, particularly those associated with teaching, tend to be neglected.

There is some evidence that a more balanced view is developing. Universities, at least in their public declarations, are recognizing their duty to serve the broader educational and cultural needs of their communities and the nation. Scientists recognized primarily for their research contributions have been and are involved in curriculum development projects such as the PSSC and Harvard Project Physics high school programs. They serve on the college science commissions and on educational development projects in foreign countries. Their involvement has encouraged other (and younger) scientists to devote some of their creative energy to professional activities outside the laboratory.

A commitment to teacher preparation by the physics faculty of a large university should quickly produce an appreciable impact upon the problem. The number of certified physics teachers prepared at present is so small that an additional five teachers per year would add a one percent increment to the national output; a large university with its resources in students and faculty should be able to recruit twenty or thirty students to an attractive program. While such an effort might require, say, half the time of three or four staff members, it need not detract seriously from the other activities of a large department. (Yet it will make the first university which achieves it the leading physics teachers preparation center in the nation.)

One of the rewards to the physicist who teaches is the satisfaction he feels in making a contribution which has the potential to spread beyond his classroom to other students in the present and in succeeding generations. When one teaches prospective teachers, this feeling is greatly intensified: it is possible to observe the effects of such efforts in a remarkably short time. A freshman student who is this year persuaded to prepare for secondary school physics teaching may in four years be influencing high school seniors, some of whom will appear in the university as physics students the following year.

Physics as a profession desperately needs to strengthen this feedback loop. If it does not, it will cut itself off from the major fraction of the educated public. Without well-educated teachers of science at the pre-college level, the alienation of the lay citizen from physics will increase and may eventually become so complete that society will no longer support an activity which it does not recognize as relevant to its welfare.

III. Building A Program

A strong commitment to teacher preparation may not be reasonable for every institution. It requires that significant resources—money and faculty time (which not every institution can afford) —be set aside for the benefit of a small number of students. The small physics department in all likelihood cannot support both an R-curriculum [1] in physics and a teacher preparation program without holding common classes, which is not recommended. (If such a department suffers from a lack of physics majors, a teacher preparation program might bring greater rewards and should be considered.) A large state-supported university, on the other hand, has the potential resources and students to justify a teacher preparation program separate from the R-curriculum. It may have also a special responsibility to the people of its state to insure a supply of teachers.

A boundary condition for any teacher program will be the state's certification requirements. For physics teachers these range from as many as 36 semester hours in physics to as little as one course in chemistry. Requirements which are extreme in either direction will cause trouble in recruiting: if they are too heavy students will be discouraged from preparing for physics teaching; if they are too weak they may encourage other institutions to offer weak programs, which may draw students away from more adequate programs. The best source of information about state requirements will probably be the university's department of education, which should be consulted in any case. Many education departments have science education specialists who can be firm and useful allies.

If conditions are favorable—the institution has the resources, the physics department has the manpower, and the state has reasonable requirements—then it becomes appropriate to consider the design of a program to prepare high school physics teachers. The following are suggestions by the PPPT on the design.

(1) *The program should prepare a teacher in at least one other field.* Of all persons who taught at least one high school physics course in 1960-61, only 4 percent taught physics exclusively.[2] Eighty-one percent taught only one or two physics classes. Reasons for this situation are not hard to find; most schools offer no more than one or two classes of physics. A full teaching load of five sections involves about 125 students.[3] Since only about one quarter of a senior class elects physics, the senior class must number 500 before a full-time physics teacher is required.

It is of course desirable that the physics teaching load per high school increase, as it is likely to if several current programs are successful. New physics courses, such as the Project Physics course from Harvard and the "Man-Made World" course being developed by the Engineering Concepts Curriculum Project [4] (which is largely physics), are being designed to appeal to larger high school audiences. Improved physical science courses for the 11th and 12th grades are being developed which can be taught by the physics teacher. Eventually a 10th grade physics course may become common. And consolidation of high schools goes on apace in rural areas. All these changes will help make it possible for more schools to hire teachers who are primarily physics teachers. But the present situation is clear, and progress is not likely to be rapid. Thus prudence demands that a preparation program for physics teachers anticipate the likelihood that its graduates will have to teach chemistry or mathematics in addition to physics in order to get a desirable position.

The multidisciplinary preparation of the physics teacher must involve other science departments. It will be found helpful in the planning of the program to organize a science education committee, representing physics, mathematics, chemistry, perhaps biology, and certainly education, which can coordinate the planning.

(2) *In the opinion of the PPPT, it is not desirable to have teacher candidates simply take the courses of the research-oriented bachelor's degree program.* The teacher's needs are different from those of the professional physicist. He does not need to learn to do quantum mechanical calculations or to learn the mathematics of general relativity. He does not need as *much* physics before the bachelor's degree as does the candidate for graduate school (although he will want more courses later). And he needs a wider background in other sciences and in the history and philosophy of science.

There are psychological aspects to consider here as well. The successful high school teacher combines an interest in science with an interest in people. He may not be psychologically motivated to compete with the more strictly research-oriented student. The experience of most schools which do not have separate

[1] The R-curriculum is the undergraduate physics curriculum which prepares one for graduate study toward the Ph.D. degree, and was so designated by the Second Ann Arbor Conference, Nov. 1962, to distinguish it from the S-curriculum, which emphasizes "the interpretation of physics and its reintegration with other parts of our culture." (Reported in *Am. J. Phys.* *31*, 328 [1963]).

[2] Secondary School Science and Mathematics Teachers, Characteristics and Service Loads (NSF 63-10).

[3] These numbers are chosen to illustrate present conditions. Lighter loads per teacher are to be recommended.

[4] Both courses are described in *Physics Today*, March 1967.

programs for teachers is simply that those who do graduate from them seldom teach.

A separate teacher program may necessitate offering a separate degree, such as the Bachelor of Science (or Arts) in Teaching and the corresponding Master's degree.

(3) *The sequence of physics courses will affect recruitment and must accommodate the likely sources of students.* We see three important classes of candidates:

Student A, who has just taken the professional introductory physics course, but who might be persuaded at this point to teach physics in high school if he were able to switch into the teacher program.

Student B, who begins with an inclination toward teaching[5] as a career, has not had a good high school physics course, and has not considered physics as a specialty. He might however take an introductory physics course for nonscience majors, and from there be attracted into physics teaching.

Student C, who in high school chose to teach physics as a career and has chosen his college or university for its preparation program. He has probably had a very good high school course and is ready for more of a challenge than the nonscientist's course offers.

These three students should enter the program at different points corresponding to their physics backgrounds. The program must allow those entrance points if it is not to cut itself off from one or another source of students. Multiple exits are also required if the program is to serve those preparing for a Master of Science in Teaching degree.

Student B represents the most likely source of new physics teachers in the Panel's opinion. Because the burden of recruiting him falls mainly on the introductory course for nonscience majors, this course will form the most important single element in the teacher program. It must attract and challenge students, yet it must remain within their capabilities.

(4) *The content of the physics courses should reflect the needs of the high school teacher.* When experienced teachers were asked what subjects should be emphasized in the preparation program, they all favored more attention to electricity and magnetism, both in theory and in the laboratory, and to electronics laboratory experience. High school students find electricity interesting and not at all intuitive. They often ask questions about electronics. Teachers need to know enough to encourage these students. The teacher should be able to make simple repairs on electronic laboratory equipment.

Analytical mechanics has not been found especially useful to the high school teacher. Modern physics (at a descriptive level) is very desirable. The teachers asked that more attention be given to applications of physics in technology and in other sciences to enable them to connect physics with some of their students' own interests and thus to motivate them.

(5) *The style of the courses should reflect the fact that the high school teacher needs a greater ability than does the research student to explain physics in words as well as mathematics.* A physics seminar is recommended to give the student practice in talking physics, but this object should be considered in other courses as well.

(6) *A course in the history and philosophy of physics is particularly important for the teacher.* One of his major tasks is to convey to those who do not go on in science an understanding of the nature of the scientific enterprise. Whereas the research student will eventually acquire this understanding through his own experience, the high school physics teacher may not. Unfortunately physicists are rarely sufficiently well versed in the history and philosophy of physics to teach it well. If one's history or philosophy department has a science specialist, it would be worth having teachers take his course.

(7) *The program should enable teachers already in service to get further training in physics.* Advancement in rank and salary usually depends upon it. Yet too often the only post-graduate courses that a teacher can take in his free time are in mathematics. Is it any wonder then that many physics teachers switch to mathematics? A teacher will not know and need not know all of his physics at the time of his graduation. It is important that he be able to take intermediate physics on Saturdays, in the evenings, or in the summers.

[5] For the purpose of this discussion, the student who enters college with no preconceived career plans may also be considered an instance of Student B.

IV. A Possible Program

This section describes a set of physics courses which can be used in a teacher preparation program flexible enough to accommodate the three types of students discussed earlier; it offers each of them appropriate physics training for three alternative goals: a teaching minor, a teaching major, or a masters degree in physics teaching.

No attention is given here to the prospective teacher's needs in other sciences, in professional education courses, or in his general education. Thus what is offered here is not a curriculum. An attempt was made to design a complete curriculum at the Minnesota Workshop, but it was felt that variations in institutional and state requirements would prevent the result from being generalizable. A four-year curriculum embodying only the advanced physics program is reported in Appendix D, but is offered only as an example of how a particular institution might apply the recommendations for physics content.

Three programs may be compounded out of the following courses as elements:

A. Introductory Physics I and II (four hours each including lab):
A non-calculus course for a general audience, not normally taken by those having had adequate physics and mathematics in high school.

B. General Physics I and II (five hours each including lab): A calculus-based course which—with either a good high school physics background or with Introductory Physics—will cover the same ground as the R-curriculum[1] professional course.

C. Intermediate Physics I and II (five hours each): Topics from the R-curriculum junior and senior courses selected for their relevance to high school physics teaching.

D. Modern Physics I and II (three hours each): A description of atomic, nuclear and solid state physics.

E. Advanced Laboratory I and II (two hours each):
Demonstrations of quantum phenomena, independent design of experiments, and an introduction to laboratory technology and shop practice.

F. Physics Seminar I and II (one hour each): Study of topics from the professional literature and practice in reporting on them.

Table IV and a flow chart (Figure 2) show how the three programs are composed.

[1] See footnote 1, page 18

TABLE IV

Physics Courses for Three High School Physics Teacher Programs

Credit Sem. Hrs.	*Course*	*Minor Program*	*Basic Program*	*Advanced Program*
4	Introductory Physics I	X	X	
4	Introductory Physics II	X	X	
5	General Physics I	X	X	X
5	General Physics II	X	X	X
5	Intermediate Physics I			X
5	Intermediate Physics II			X
3	Modern Physics I		X	X
3	Modern Physics II			X
2	Advanced Laboratory I		X	X
2	Advanced Laboratory II			X
1	Physics Seminar I		X	X
1	Physics Seminar II			X

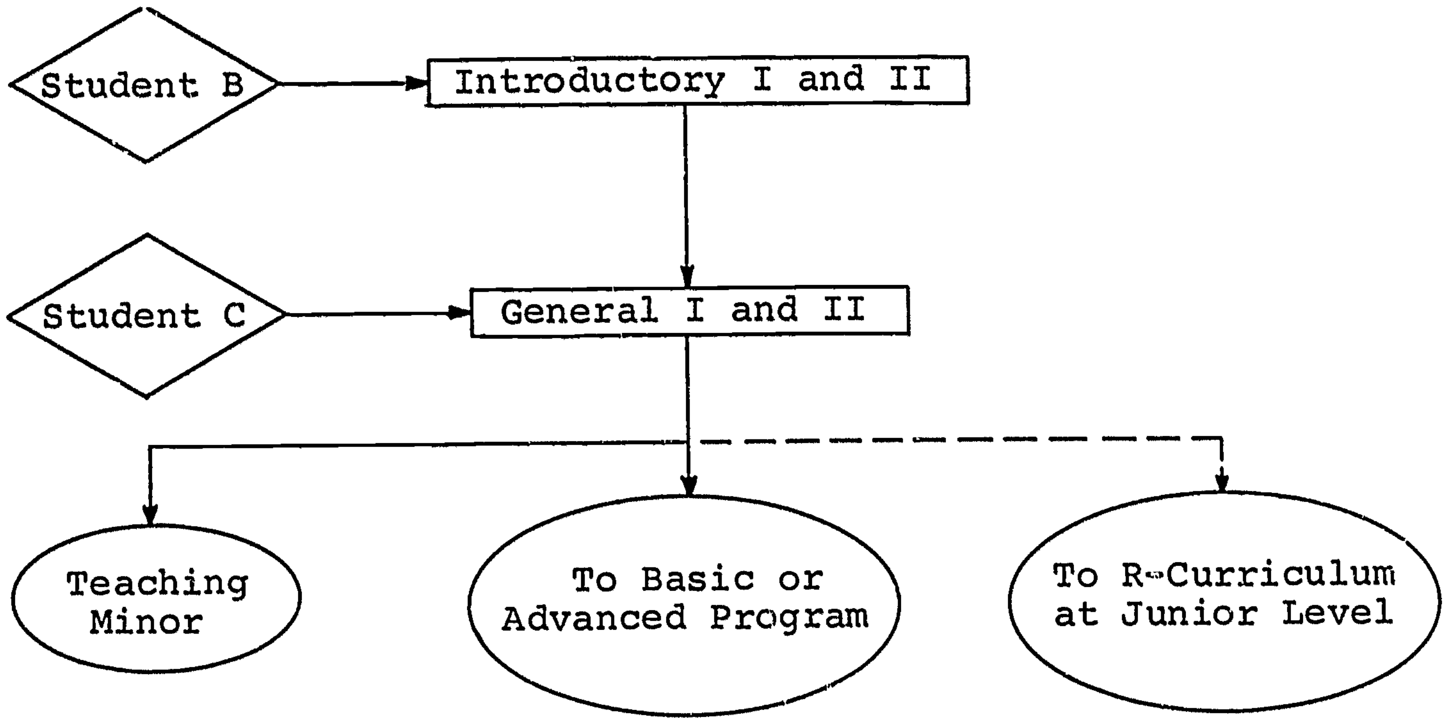
The *advanced program* comprises all of these courses except Introductory Physics. It serves primarily the student with a good high school background who enters with the intention of becoming a high school physics teacher (Student C in the language of Section III). The program will carry 32 semester hours credit, and should satisfy the subject-matter requirements for the Master of Arts in Teaching. Since the advanced program contains more physics courses than either of the other programs, it will be the most difficult to fit into a complete four-year curriculum including the mathematics, chemistry, education, and general education courses. To show how it might be done, a model four-year curriculum is outlined in Appendix D.

The *basic program* is for Student B, who is attracted into physics teaching because of his experience in Introductory Physics. In addition to Introductory Physics I and II, it comprises General Physics I and II, and the first semesters of Modern Physics, Advanced Laboratory, and the Seminar. This 24-hour sequence may be completed in the usual four-year college period even if started as late as the sophomore year.

The *minor program* consists only of Introductory Physics and General Physics, and could be started in the junior year. Although comprising only 18 hours credit, this program would prepare the student more thoroughly than two-thirds of those now teaching some physics. The graduate would be expected to fill out his knowledge of physics through in-service training.

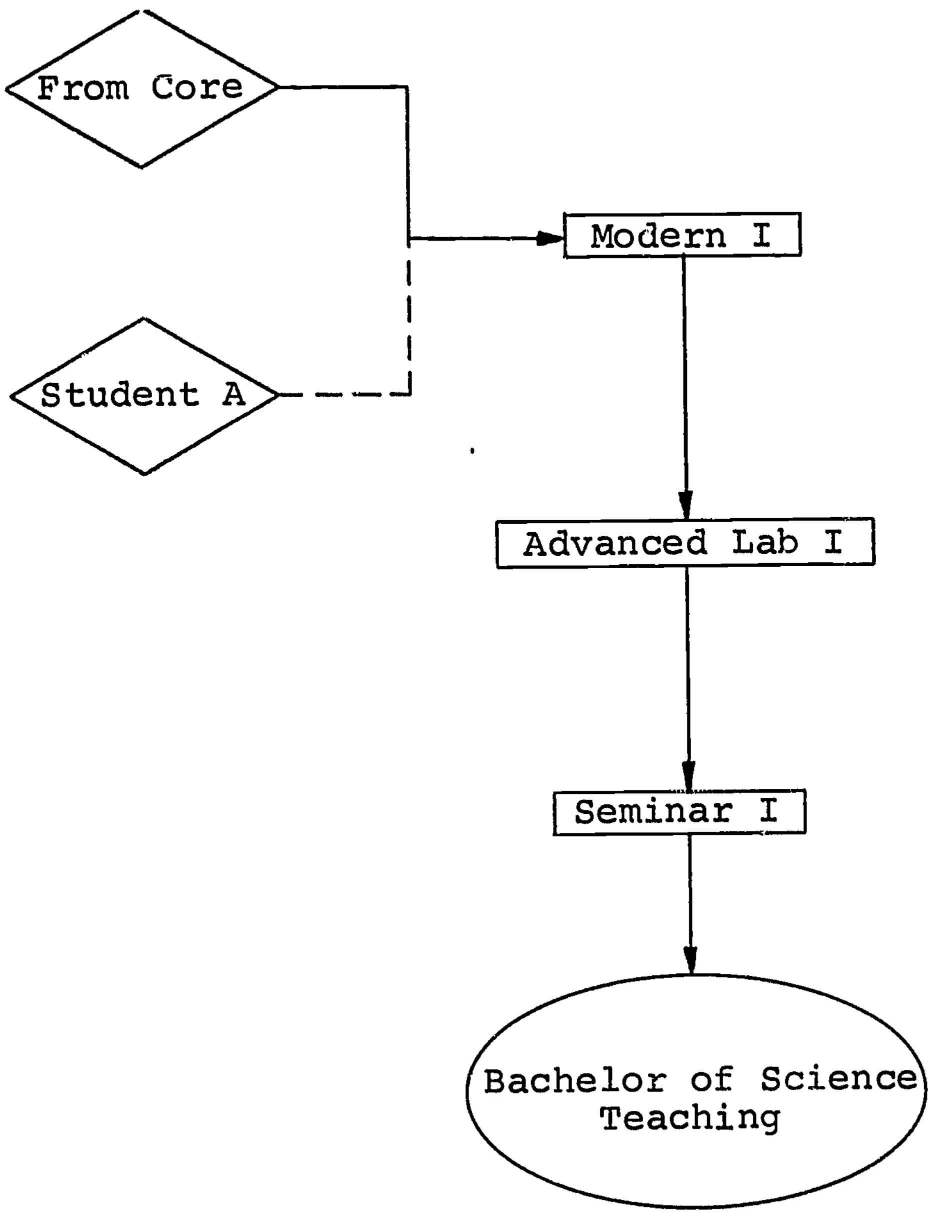
Figure 2

A. Core Courses



(Figure 2)

B. Basic Program



Figures 2A and 2B. See Figure 2C, next page, for caption.

(Figure 2)

C. Advanced Program

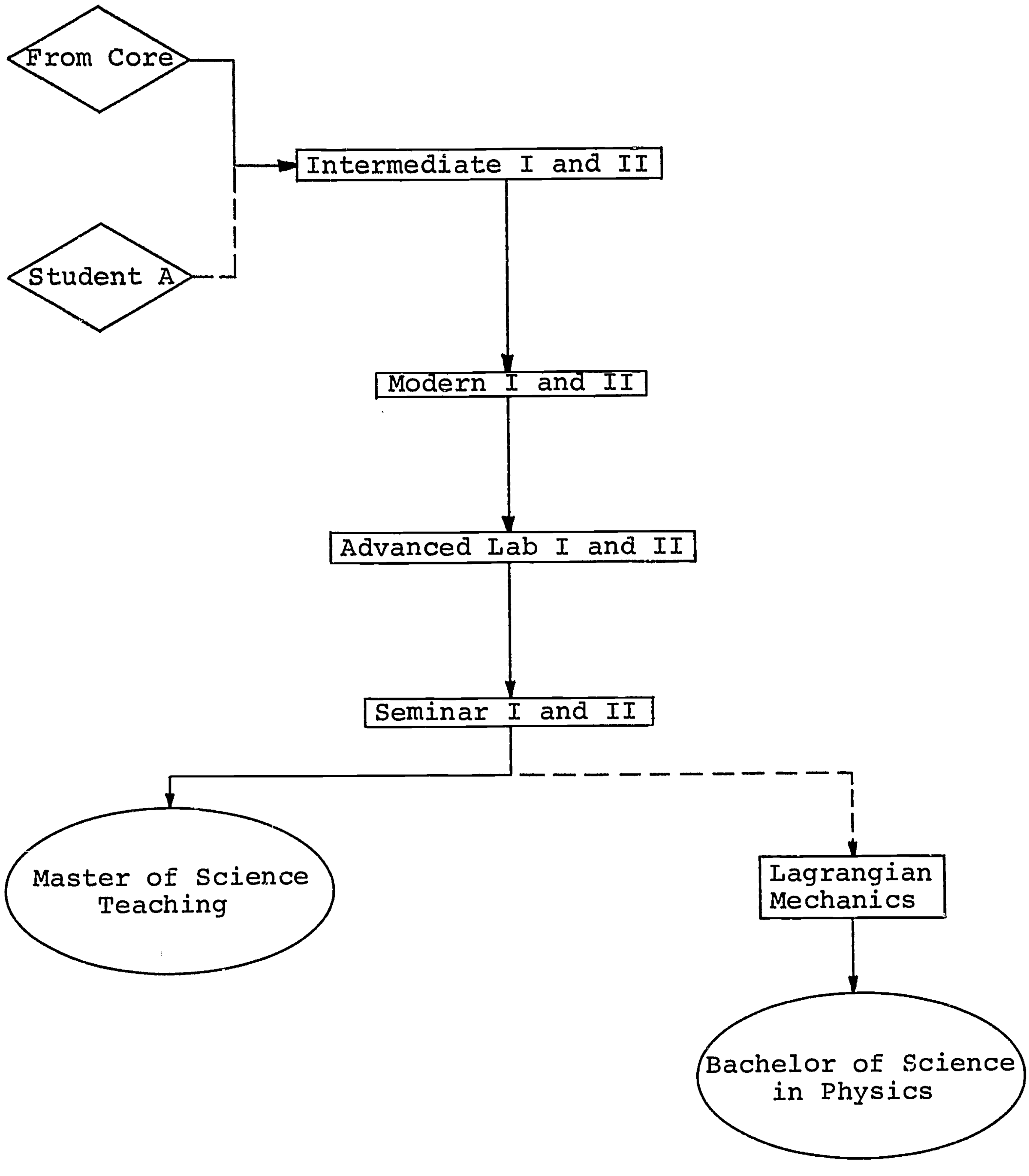


Figure 2C. (See parts A and B on previous page.) Flow charts for the physics courses of physics teacher preparation programs. Compare Table IV. Typical students A, B, and C are described on pages 17 and 18. The dashed lines indicate transfer to and from the R-curriculum (for graduate-school-bound physics majors).

What about Student A, who switches to teacher preparation after the R-curriculum introductory course? Since Introductory Physics and General Physics provide approximately the same coverage as the introductory physics major course, Student A should fit into the Intermediate Physics course with little adjustment. (Conversely, the graduate of General Physics who is exceptionally competent in mathematics should be capable of switching into the junior level of the R-curriculum if he so chooses.)

A final feature of the sequence is that the courses beyond General Physics may serve (if scheduled at appropriate times) the physics teacher already in service who wishes to continue his studies toward a master's degree in teaching.

The courses are described in more detail below with emphasis on how they differ from similarly named courses in the R-curriculum.

Introductory Physics I and II

This course, from the student's point of view, is an introduction to physical phenomena and theory such as any well-educated person in the twentieth century must surely have. From the point of view of teacher preparation, however, it is a recruiting ground and as such, it deserves very careful attention. Its success in attracting students who are initially indifferent to physics will determine the success of the teacher program.

Students entering this course will probably have weak backgrounds in physics and mathematics and will not be strongly motivated in science. The course should be designed not solely to teach physical principles but also to shape the student's attitude toward physics. If he finishes the course believing that physics is exciting and understandable, then he may even be persuaded to teach it.

Some existing courses, usually called "physics for the nonscientist," may already serve this purpose and the sequence might be built on them. Examples of such courses can be found in the "Proceedings of the Boulder Conference on Physics for Nonscience Majors," [1] which contains not only expanded course outlines, but also discussions of tactics and strategy and such resources as paperback reading lists.

But further experimentation is very much needed. Courses could, for instance, be developed which try to adapt to college use the "learning by discovery" method now so widely used in the schools.[2] This type of course leads a student to puzzle things through for himself, offering both the experience of being a scientist and the satisfaction that accompanies success. Furthermore, it might provide a model for teaching high school physics since teachers generally teach as they are taught. Appendix C provides some ideas for the content of a discovery-oriented introductory course.

Whatever form it takes, the course must not be too demanding mathematically. It should have a larger verbal component than most physics courses. Students should be encouraged to use words (and their hands) to explain phenomena in terms of models and the application of basic principles; mathematical description should be the final step. The course should make use of auxiliary materials on history, biography, and philosophy and rely more heavily on reports, papers and essays in addition to problems. For example, students could read popularized scientific articles critically or be asked to discuss pseudoscientific articles available in newsstand publications.[3]

The examinations must reflect the goals of the course. Questions should test not only problem-solving ability, but the ability to express in words and pictures clear understanding of physical ideas.[4]

General Physics I and II

One of the strong boundary conditions the Workshop laid on the course sequence for prospective teachers was that there be more than one entrance and exit point. General Physics is the key to this flexibility, for it must bring the good, but underprepared, student from Introductory Physics I-II to a level of understanding which allows him to transfer into the R-curriculum if he wishes, and yet must be a satisfactory beginning course for the well prepared student (Student C) who is taking the advanced teacher preparation program.

This duality of purpose will make its design difficult. It must give the exceptional student sufficient experience with the analytical approach to physics and with problem solving to enable him to compete with physics majors from the R-curriculum introductory course. Yet it must not over-emphasize the analytical approach and must continue to build the future teacher's "feel" for physics and his ability to deal verbally with the application of its laws. The chief design element must surely be diversity of subject matter, of instructional approaches, and of expectations.

While no existing text can carry the full burden of the course, there is enough printed material upon which the instructor can draw: for example, pertinent material in the Feyman lectures [5] (in addition to

[1] Available from the Commission office.

[2] "Physical Science for Nonscientists" (*Physics Today*, March 1967) provides a model of such a course, although at a less intensive level.

[3] For example, a magazine called *Fate* (July 1964, p. 36) reported the death of a technician in a physical laboratory when his head passed through the intersection of two lines of magnetic force.

[4] For examples of such questions see L. Nedelsky, *Science Teaching and Testing*.

[5] R. P. Feynman, M. Sands, R. Leighton, *The Feynman Lectures in Physics*, 3 vols. (Addison-Wesley, 1964).

more standard approaches); the wealth of inexpensive paperbacks, particularly the Momentum Books [6] and perhaps even the Science Study Series [7] (either for subject matter presentation or background reading); [8] the trial Monographs put out by the CCP and the University of Washington [9] and other such monographs. Once the instructor has outlined his course, AAPT Resource Letters [10] may guide him to appropriate texts and articles.

It is especially important for high school physics teachers to be competent in electrical circuits and electronics, and the General Physics laboratory is an appropriate place for them to learn this. It might, for example, be based on parts A and B of the Berkeley Physics Course Laboratory. The student may be able to carry out open-ended experiments, which allow undirected exploration of physical systems using modern instruments. Here he will gain the experience and confidence he will need to present the experimental side of physics to his students.

Intermediate Physics I and II

Intermediate Physics is a selection of classical physics from the R-curriculum junior-senior courses (and some graduate courses) chosen for their relevance to high school physics. The course will serve those undergraduates who elect the advanced preparation program, as well as those teachers already in service who wish to continue their study of physics after graduation. For this reason the course should carry credit toward a Master of Science in Teaching degree, and be offered at a time convenient to the working teacher.

The course might include:

1. The mechanics of damping and forced damped harmonic motion, with examples both in ac circuits and in the nature of absorption line shapes in atoms and molecules.
2. The thermodynamic and statistical interpretations of entropy.
3. A relativistic approach to magnetism, such as presented by Feynman [11] or Purcell.[12]
4. Maxwell's equations and the E-M boundary conditions with applications in simple geometries.
5. Physical optics, the solution for the refracted and reflected waves using the quasi-static E-M boundary conditions, birefringence, stellar interferometers, non-linear optics, etc.
6. Discussion of the electromagnetic radiation due to accelerated particles and oscillating dipoles.
7. Wave motion in mechanical and electrical transmission lines with direct comparisons to molecular vibrations in solids.

Many applications of these classical ideas could be cited from modern physics, as well as from chemistry and astronomy.

A more analytical and mathematical approach is possible in this course in view of the mathematical sophistication the students should have acquired at this point.[13] Nevertheless, this course would continue to emphasize the understanding and explanation of the physics as opposed to the mathematical analysis of complex cases.

At the end of this year, the exceptional student would almost be prepared to transfer to the R-curriculum if he should so choose, entering with a senior course in modern physics. His single important deficiency would be in Lagrangian mechanics, which could be made up with a two-credit course.

Modern Physics I and II

Modern Physics I, part of both the basic and advanced programs, is an introduction to wave mechanics and to the physics of atoms and nuclei. It treats the Bohr circular orbit model, the Schroedinger wave formulation of quantum mechanics, two-state systems (as in chapters 1-4 of the Feynman lectures, vol. 3), discussion of electron distribution in excited states of the hydrogen atom, application of wave mechanics to atoms having several electrons, shell structure, valence, simple nuclear systematics, binding energy as a function of Z and A, modes of radioactive disintegration, fission and fusion.

The second semester of Modern Physics would build upon the quantum theory presented in Part I, and would include a discussion of solid state and low temperature phenomena and nuclear and fundamental particle physics.

Advanced Laboratory

The advanced laboratory emphasizes quantum phenomena and teaches basic laboratory and shop practices. Useful apparatus for the course would include some of the following: a variety of electronic circuitry or components, vacuum systems technology (gauges, pumps, etc.), nuclear radiation detection equipment of various types, speed-of-light equipment

[6] Momentum Books, a series of monographs in physics, published by D. Van Nostrand, under the editorship of Walter C. Michels.

[7] Published by Doubleday; a series of high school level monographs.

[8] Of particular use is the Resource Letter Col R-1, *Am.J.Phys.* *35*, 1 (1967) on collateral reading for physics courses.

[9] A list of monograph titles and authors appears in *Instruction by Design*, a conference report available from the Commission offices.

[10] See *Am. J. Phys. 34*, 540 (1966).

[11] Feynman, et al. *op. cit.*

[12] E. M. Purcell. *Electricity and Magnetism*. Berkeley Physics Course: vol. II. (New York, McGraw-Hill Book Company, 1965).

[13] See the model complete curriculum for the advanced program, Appendix D.

such as a rotating mirror, a magnet for Hall effect studies, etc., lasers of several kinds, spectrometers with resolution good enough for the Zeeman Effect, nuclear magnetic resonance equipment, subcritical nuclear reactor cones and reflectors, particle accelerators (½ MeV to 4 MeV). A small shop for making parts is essential.

Physics Seminar

The Physics Seminar can serve three important functions:

1. The student should become familiar with professional and general scientific literature, including original research papers (especially from 19th century sources) and contemporary review material, such as may be found in the *American Journal of Physics, The Physics Teacher, Contemporary Physics, Physics Education* and *Scientific American.*
2. He should learn to read and understand unfamiliar physics without help.
3. He should learn to present material, explain it, and put it in its proper context.

There are advantages to the student in presenting ten-minute talks instead of one-hour papers in the seminar: he can get quick feedback and discussion, his turn comes more often, and he is rewarded for conciseness and careful use of time. Only after skill is established with the ten-minute talk should the more ambitious one-hour talk be undertaken.

Students might do projects, either experimental or theoretical, on which they would write reports or give talks. Projects involving connections between physics and other disciplines—in geophysics, astrophysics, meteorology, oceanography, physical chemistry, biophysics, metallurgy and a variety of engineering disciplines[14]—will be especially useful for the high school physics teacher. Projects in the teaching of physics are also a possibility.

It has been found that speakers (as well as actors, dancers, and athletes) rapidly improve when they are able to see themselves on video-tape immediately after their performance. The short time lapse between performance and viewing greatly accelerates learning and makes it possible for a student to repeat his performance immediately to correct some of his perceived faults. In some education departments, courses in teaching methods include this video-taping experience, but if it is not included in the education course, it might go into the physics seminar. (This training would also help to prepare research students to give talks at professional meetings.)

[14] For topic suggestions, see "A New Look at Curriculum R," CCP *Newsletter* no. 12, February 1967.

V. Some Existing Programs

While national practice in the preparation of high school physics teachers may be pictured as a desert landscape, it is not without its oases. A few physics departments have concerned themselves about high school teachers for years and have succeeded in recruiting students to this career. The major part of the burden has fallen to teachers colleges and to universities or state colleges from that tradition. Below are descriptions of three successful programs[1]: one at a teachers college which in physics offers only the bachelor's degree; one at a large state university—once a state teachers college—which is greatly expanding its physics program and now offers the master's degree; and one at a large university with a long-established and highly regarded Ph.D. program in physics.

These programs are mentioned here as alternatives to the Workshop's program, alternatives which fit the requirements of the states in which they operate. None of them have all the features of the Workshop program. But whereas the Workshop program exists at present only on paper, these programs have already passed the test of practicability.

It appears, from the PPPT informal survey, that the leading producer of high school physics teachers[2] is Kansas State Teachers College, Emporia, which graduates an average of 18 teachers per year, each having taken 19 hours of physics, 18 hours of chemistry, 18 hours of mathematics, and usually eight to ten hours of biology.

Depth is sacrificed for breadth, since most Kansas high schools offer chemistry and physics in alternate years and require one teacher to teach these as well as mathematics. The physics courses are:

Course Title and Credit (semester hours)	
College Physics (non-calculus)	10
Modern Physics	3
Advanced Physics Laboratory	3
Intermediate Physics	3

The Intermediate Physics course covers advanced material on light, heat, electricity and mechanics.

Nineteen hours in physics may seem a bit light for a physics teacher. One must remember, however, that *two-thirds* of those now teaching high school physics have taken less than 18 hours in physics, and that the KSTC faculty is able to persuade an average of 18 teachers per year to take this program.

A more ambitious program is required by the state of Indiana and is offered at the Indiana State University, Terre Haute (formerly Indiana State Teachers College). While the professional physics curriculum at Indiana State is being expanded and a master's degree in physics is now offered, teacher education is a strong continuing activity; an average of 14 physics teachers are graduated per year. This program has existed for more than 15 years and is now paying off handsomely for the present research program; most of the physics teachers in western Indiana high schools are graduates of Indiana State and advise their promising physics students to go there, thus forming a "farm system" for recruiting physics majors.

At Indiana State University the prospective teacher may elect either a teaching major, comprising 32 hours in physics and 8 in chemistry, or a minor, comprising 24 hours in physics. The minor is more popular by 2 to 1. The courses are those also taken by physics majors. The *minor* program consists of:

Course Title and Credit (semester hours)	
Intermediate Physics	10
Analytical Mechanics	3
Electricity and Magnetism	3
Modern Physics	3
Electrical Measurements	3
Electives	2

The additional requirements for the teaching major comprise three hours in electronics, five additional hours of electives, and eight hours of general chemistry.

One is not limited to the teachers college or the former teachers college in searching for important producers of high school physics teachers. An outstanding example is Indiana University, Bloomington, which is well known for its excellent graduate program in physics. The physics department maintains good relations with the education department and the public schools of Indiana through a university liaison staff member with the title of Coordinator for School Science. Over the past five years an average of eight physics teachers per year have graduated from Indiana University, most of whom have physics as a minor or second teaching field. Some do take the physics major for teachers, which comprises 31 semester hours credit.

The Indiana University curriculum for physics teacher preparation is given below:

Course Title and Credit (semester hours)	
General Physics—mechanics, heat, sound, light, electricity, and magnetism (includes laboratory)	10
Contemporary Physics	3
Circuit Analysis and Electrical Measurements (includes laboratory)	4

[1] Several other schools produce significant numbers of high school physics teachers besides the three discussed in this section. Those chosen for discussion were ones which came to our attention early and were visited by the staff representative of the PPPT.

[2] A "high school physics teacher" for present purposes is one who has at least 18 semester hours in physics and who is certified in his state to teach physics.

Theory of Electricity and Magnetism	3
Optics (includes laboratory)	5
Introduction to Quantum Mechanics	3
Atomic and Nuclear Physics	3

With an additional ten hours of general chemistry the student has then met the subject matter requirement for the teaching major in physics. A teaching minor comprises 24 semester hours not including the general chemistry. Note that this curriculum does not include analytical mechanics, or heat and thermodynamics or statistical mechanics but is heavy on electricity.

The course in methods of teaching science offered by the IU education department is enthusiastically received by its students. It is challenging and realistic, involving the students with the actual materials they will be using in high school science teaching.

The success of these programs is most likely due to factors which do not appear in a table of courses. In each case a personal approach is made to persuade students to take the courses. At KSTC a faculty member interviews each student who makes an A or B in the introductory physical science course and discusses the possibilities of high school physics teaching. The graduating physical science teacher is visited by a member of the physics department from time to time. At Indiana State those of the physics faculty concerned with teacher preparation maintain records on the careers of their graduates and keep in touch with them through a newsletter. The present Coordinator of School Science for Indiana University, who was once a high school principal as well as a high school physics teacher, is very effective in getting high school students to visit the University and in getting physics faculty members to meet with them, demonstrate interesting pieces of equipment and talk about their research.

These physics departments succeed in producing teachers because they are close to the high school situation, they are realistic in what they require of the students, and they work hard at recruiting them. They show us that it can be done.

VI. Recruiting

The most beautifully designed curriculum will be a total failure unless students can be brought into the courses. Recruiting is usually a passive activity in physics: it is assumed that if one offers good courses the students will automatically come. While this approach is moderately successful in attracting physics majors, something more is needed for prospective teachers. Unfortunately, many of the students we wish to attract enter college with a negative bias toward physics.

In Section III we identified three principal types of students who seem to be good targets for recruitment. Student A is in physics or engineering but at the end of his sophomore year decides that research is not for him. Student B thinks he might like to teach, but physics does not seem to be a reasonable specialty for him. Student C comes to college knowing that he wants to teach high school physics. The recruiter must persuade Student A to teach, Student B to take physics, and must attract Student C to his institution.

Student A is the dissatisfied customer in the professional course. He ordinarily would drop out of physics and never be seen by physics faculty, making it difficult to recruit him for anything. Since it sometimes happens that such a student approaches a physics professor to discuss physics teaching as a career, it is worthwhile having it widely known among students *who* in the department is receptive to discussion of teaching. A mid-term lecture could be given on careers in physics, among which teaching should of course be mentioned.

The introductory course in physics for nonscientists is the principal recruiting ground for Student B. Each boy or girl who enters the door of this course should be viewed as a possible candidate for the program. After the first exam, the grade list will identify those students who have the potential to teach high school physics; the A and B students can be interviewed individually.

Student C doesn't need any persuasion; he just needs to be told where good training exists. This, of course, requires interaction with the high schools and the high school physics teacher. Simply going out and visiting high schools often can generate contacts with interested students. In any case it makes sense to befriend the high school physics teacher, who is often isolated from the mainstream of physics. One can magnify one's effectiveness by visiting *area meetings* of physics teachers.

A visit by the university physics club to a high school would serve not only to interest the high school student in physics but to interest the college student in teaching. An analogous experiment is reported in the 1966 Annual Report of the Education Development Center. The idea was to get PSSC physics students to spend a few hours teaching third grade students about simple electrical circuits—batteries and bulbs. Each high school student taught a small group of third graders essentially through the discovery method. The excitement was high. Letters from the high school students include comments such as "the most exciting experience of my life" and "a great thrill." Apparently a taste of teaching stimulates an appetite for it.

Although large numbers of women choose careers in education, and appreciable numbers of them specialize in other sciences and mathematics, very few go into physics or physics education. The percentages of women among the new teachers each year are 41 percent in biology, 45 percent in mathematics, 33 percent in chemistry, and only 16 percent in physics. A sizeable increase in the number of physics teachers could be made by enlisting some of the bright young women who are apparently insulated from physics by a cultural bias.

As a matter of fact, high school physics teaching would be a very good occupation for a married woman. Certified in physics, she should have no difficulty in getting a teaching job no matter where her husband lives. In recruiting women, an example would probably be most persuasive; there do exist women high school physics teachers who could be invited to participate in recruiting.

Some scholarship money is available for the prospective teacher. Several states have a plan whereby the prospective teacher may borrow money for his education and be forgiven repayment if he makes good his promise to teach after graduation. There is usually some university or college office whose responsibility it is to be aware of available scholarship money. The education department will know of government programs for this purpose. Education is the second largest budgeted activity of the federal government, and there are signs that teacher training is beginning to receive its share of attention.

An essential thing to discuss in recruiting is salary. Nobody is going to go into high school physics teaching to get rich, but the salary situation has improved markedly in recent years. Data for 1966-67 show among the largest school systems (those with enrollment in excess of 100,000) that teachers with a bachelor's degree earn typically between $5,000 and $8,600 (see Table V). (The median of minimum salaries and the median of maximum salaries is meant here.) A master's degree earns from $500 to $1000 more. *These are academic year salaries, for approximately nine and one-half months work.* The minimum salary

TABLE V

Minimum and Maximum Academic Year Salaries of Classroom Teachers, 1960-66, by Degree Held, in United States School Systems of Enrollments above 100,000. (Median data.)

	Bachelor's Degree		*Master's Degree*		*Highest Level*
Year	*Min.*	*Max.*	*Min.*	*Max.*	*Max.*
1960-61	$4,500	–	–	$7,500	$ 7,925
1961-62	4,650	–	–	7,750	8,000
1962-63	4,700	$7,300	$5,000	7,700	8,550
1963-64	5,000	7,800	5,200	8,214	9,000
1964-65	5,000	8,000	5,270	8,475	9,410
1965-66	5,275	8,610	5,608	9,214	10,087
1966-67	5,400	8,708	5,815	9,390	10,397
Average Increase per Year	140	82	163	338	369

has been increasing at the rate of approximately $250 per year while the maximum salary has gone up about $500 per year over the past five or six years.[1]

The above figures do not tell the whole story. Directors of academic year institutes are often approached to recommend candidates for positions in private schools. Salary schedules at these schools are often more flexible and may go as high as $13,000 per academic year for a teacher who has a master's degree in science education and is a graduate of the institute. While salaries above $10,000 per academic year are unusual, they do exist. Because of the shortage of physics teachers, the well-prepared teacher usually has his choice of school systems. He is free to choose those with more attractive pay schedules, as well as those with more attractive working conditions.

Free summers offer additional opportunities for the high school physics teacher. The summer period is often the time for further education, which in turn practically insures an increase in salary. Some possibilities for summer income are:

(1) Industrial research organizations,

(2) Academic institutions, either research groups or summer institutes for teachers,

(3) Government research laboratories,

(4) Teaching in summer school.

We must not oversell high school teaching. In many areas of the country salaries are clearly insufficient to hold good people for long. In most areas the conditions of work—numbers of students per class, amount of released time for equipment upkeep, equipment money—are far from ideal. If we are to recruit eager, able young people with the argument that physics teaching has many rewards other than financial, then we must do our best to ensure that such rewards are forthcoming. Our responsibilities include maintaining our contacts with these teachers, keeping then informed of important physics research advances, and fighting for reduction of their teaching loads as hard as we fight on our own behalf.

No matter how one goes about recruiting, the most important element is personal. We must prove to the undergraduate by our actions as teachers and as physicists that physics is interesting, that he has a chance to learn it, and that we will help him learn to teach it. Only then can we successfully compete for his professional allegiance.

And the further vigor of our profession may depend on it.

[1] NEA Research Report 1966–R 17, October 1966, Table 7, page 19.

APPENDIX A

Participants in the Minnesota Workshop

Carol (Mrs. L. L.) Baggerly
Trinity Valley School
Fort Worth, Texas

Clarence Boeck
College of Education
University of Minnesota

Philip DiLavore
Department of Physics and
Department of Secondary Education
University of Maryland

George Freier
School of Physics
University of Minnesota

Ben A. Green, Jr.
Commission on College Physics

Jay A. Kettlehut
Ann Arbor High School
Ann Arbor, Michigan

Peter Lindenfeld
Department of Physics
Rutgers

Robert N. Little
Department of Physics
University of Texas

Peter G. Roll
School of Physics
University of Minnesota

Richard H. Sands
Department of Physics
University of Michigan

Arnold A. Strassenburg
American Institute of Physics

James H. Werntz, Jr.
School of Physics
University of Minnesota

Bernard T. Young
Department of Physics
Sam Houston State College
Huntsville, Texas

APPENDIX B

Members of the Panel on the Preparation of Physics Teachers

Robert L. Sells, Chairman
SUNY at Geneseo

Philip DiLavore
University of Maryland

Ben A. Green, Jr.
Commission on College Physics

W. Thomas Joyner
Hampden-Sydney College

Robert N. Little
University of Texas

Melba Phillips
University of Chicago

F. James Rutherford
Harvard Project Physics

Richard H. Sands
University of Michigan

Malcolm H. Skolnick
SUNY at Stony Brook

Arnold A. Strassenburg
American Institute of Physics

Philip Youngner
St. Cloud College

APPENDIX C

A Discovery Approach to Introductory Physics

ARNOLD A. STRASSENBURG
American Institute of Physics

Most people have a natural curiosity about the way things work. Unfortunately this curiosity is frequently stifled in formal science courses by excessive concern for deducing events from abstract general principles which are unknown to the neophyte scientist and by a demand for analysis incorporating symbolism which is unfamiliar to individuals with limited training in mathematics. A way to capitalize on the natural curiosity of a student with limited background in science and mathematics is to focus his attention on interesting physical phenomena. He should be encouraged to make models of how the system under investigation behaves, and to design tests which will check the validity of the models. Many questions should be asked about each new phenomenon, and the instructor should guide the students to devise methods of seeking answers to their own questions. This spirit of fun and exploration can stimulate the interest and imagination of the beginning student.

The phenomena selected for study during the first year of the course sequence can be illustrative of several major principles of physics. The students should be given opportunities to discover several applications of a single principle so that the value of abstraction and generalization in summarizing experiences becomes apparent. What topics and what modes of presentation lend themselves to accomplishing these goals?

One might start with demonstrations of optical phenomena, because of the great visual appeal, the diversity of effects, easily exhibited, and the adequacy of the (wave) model which one ultimately proposes to encompass them. Geometrical effects such as reflection at a single plane surface might be investigated first. The students might propose that particles emitted by the source bounce off the mirror and into the eye. Multiple images formed by corner mirrors are interesting and would provide an extension of the hypothesis to a more complex event. Refraction would require an additional assumption about the interaction of the particles with matter. Dispersion by a prism would add another dimension of complexity and require further refinements of the theory. At a later stage students would be given diffraction gratings to play with; demonstrations of intensity patterns on the wall resulting from laser light passed through various slit arrangements could be examined. These phenomena would demand a drastic revision in the class model of the behavior of light. To stimulate thinking in terms of a wave model, film loops showing ripple tank interference patterns could be shown.

And so it would go: observation, model-making, testing hypotheses under new situations, and thinking through again the consistency of the model. At all times the discussion would concern phenomena that students had observed, and they would be intimately involved in the processes of observation and reasoning.

Naturally, many of the students would already know what the "right model" is before the course starts, and they would be reading about light in a number of standard references and paperbacks. (There would not be a conventional textbook until an appropriate one is written.) This need not spoil the fun. Since they probably would not previously have been required to propose for themselves reasonable hypotheses based on available evidence, the approach would provide a new challenge which the whole class could turn into a kind of game.

What other topics could be similarly treated in a one-year course which involves six to eight semester hours of the students' time? There should certainly be a unit on motion, starting with objects on which there is no net force (dry-ice pucks, air tracks and tables). One could then study the effects of forces on motion, not necessarily arriving at a quantitative expression of Newton's Second Law, but patiently building intuitively the concepts of force, mass and momentum. A clear statement of the first law would certainly emerge as an idealization of observations, and sufficient evidence could be presented so that students would be led to a recognition of the qualitative content of the second and third laws. For example, they could understand in qualitative terms the condition of weightlessness during orbital travel around the earth in a satellite.

Other units which could be developed in this style include (1) forces between electric charges, and (2) the effects on substances of adding heat. One would certainly want the class to develop a molecular hypothesis before the year is over. The unit on heat would contribute to this, but it might also be desirable to introduce much other evidence such as Brownian motion and electrolytic phenomena. It is not at all clear that this can be made convincing through experiments the students could perform; it might be necessary to develop many demonstrations and rely on filmed experiments. Perhaps a unit on atomic physics should be included for which one abandons completely the discovery approach and develops the concepts in a more conventional historical framework. This could still be made more interesting than is done in the usual didactic lecture and textbook course if the reading assignments are selected carefully and students are encouraged to ask questions and express ideas in class.

This approach covers material very slowly. There are many facts usually included in an introductory course which students will not learn in this first year. Many interesting areas of physics must be omitted if some are to be explored thoroughly. The students will not learn to solve problems in this course. Two things, however, one hopes will be accomplished:

(1) Students will develop an interest in physical phenomena and a desire to understand why things happen as they do. They enjoy studying science if they are personally involved.

(2) Students will develop an intuitive understanding for a number of important physical concepts. This will give them a sense of confidence in their ability to go on to a more quantitative approach.

The second year course should provide them with the more quantitative approach.

APPENDIX D

A Four-Year Curriculum Embodying the Advanced Physics Program

R. H. SANDS
University of Michigan

The schedule of courses given in Table VI is an example of a four-year curriculum for Student C, the student who comes to the university with the intention of preparing to teach high school physics. He is presumed to have had a good high school physics course and to have some facility with high school algebra and trigonometry.

In addition to the advanced physics program, this curriculum provides mathematics through differential equations, two semesters each of biology and chemistry, and one semester each of geology, meteorology, and astronomy. This should prepare the student for physics as a major and principal teaching field and general science as a minor and secondary teaching field.

Education courses are begun in the junior year and include an early introduction to teaching experience (teaching his classmates) in addition to the usual directed teaching practice in the high school.

Although the curriculum allows 30 semester hours for electives or distribution requirements, it does not pretend to be flexible. A determined student who knows in advance what he wants to do can accomplish the objective stated above in four years. Allowing a fifth year would permit a more comfortable pace and would permit the directed teaching to be concentrated in one semester off campus.

TABLE VI

A Four-Year Curriculum Embodying the Advanced Physics Program

FIRST YEAR			
Analytical Geometry and Calculus	4	Calculus II	4
Biology I	4	General Physics I	5
Elective or Distributive Requirement	3	Biology II	1
Geology I	4	Elective or Distrib.	3
	15		16
SECOND YEAR			
Calculus III	4	Differential Equations	4
General Physics II	5	Intermediate Physics I	5
Chemistry I	5	Chemistry II	5
Elective or Distrib.	3	Elective or Distrib.	3
	17		17
THIRD YEAR			
Intermediate Physics II	5	Modern Physics I	3
Educ. Psych.	3	Advanced Laboratory I	2
Elective	2	Intro. to Teaching	2
Astronomy I	4	Elective	3
	16		13
FOURTH YEAR			
Methods of Teaching	3	Methods of Teaching	3
Directed Teaching	4	Directed Teaching	4
History of Physics	3	Elective	4
Modern Physics II	3	Advanced Laboratory II	2
Physics Seminar I	1	Physics Seminar II (1)	1
	14		14

A total of 122 semester hours.