AAPT/NSTA high school physics examination

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For many years the American Chemical Society (ACS) under the direction of Ted Ashford of the University of South Florida, in cooperation with the National Science Teachers Association (NSTA), has produced high school chemistry examinations that are used by teachers in the United States. When Tim Ingoldsby became the Staff Physicist for AAPT in 1979, he noted a large number of requests for a similar examination that could be used by physics teachers. One of the early proponents of this idea was Bill Arnold of Fairmont West High School, Kettering, Ohio, who was then the High School Division Director of NSTA. Tim and Bill approached the governing boards of AAPT and NSTA, who encouraged the formation of a High School Physics Examination Development Committee. During the AAPT 1980 summer meeting at Troy, New York, the AAPT Committee on Physics in the High School appointed a subcommittee consisting of Crispin Butler (Middlebury, VT), Bill Layton (Santa Monica, CA), Willa Ramsay (San Diego, CA) and Tim Ingoldsby to develop a formal proposal and guidelines for development of the examination. This proposal was approved by AAPT and NSTA during the winter of 1980-81. A copy of this proposal is still available from Tim Ingoldsby. Highlights of the proposal were:

1. The purpose of the project was to provide high school teachers with a low cost (under $1.00) examination that would permit them to compare the achievement of their physics students with students in the rest of the country.
2. In order to keep the emphasis on physics, the mathematics used in the examination should not exceed that generally taught in high school Geometry and Algebra 1.
3. The development timetable called for the examination to be available in the spring of 1983.
4. Although the original proposal called for free-response as well as multiple-choice questions, the committee later decided to limit the examination to five-alternative multiple-choice questions.
5. Students were to be permitted to use calculators; however, the questions should be designed to minimize the need for a calculator.

In the March 1981 *Announcer* a call appeared for AAPT members to participate in the writing and editing of questions for the examination. The first meeting of the Examination Development Committee was held under the direction of Tim Ingoldsby during the Spring 1981 NSTA meeting in New York. Two criteria were used to select the committee members. They had to be presently teaching introductory physics in high school or college and they had to volunteer to write and edit questions. The 20 teachers who attended the initial meeting recommended a list of topics that should be included in the examination (Fig. 1), and each teacher selected four of these topics on which to write questions. The topics and their distribution are not intended to represent an absolute standard, but rather represent the average teaching practice of members of the examination committee. After this meeting applicants for Test Committee Director were interviewed by Linda Perez of J. Frank Dobie High

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Topic Distribution for AAPT/NSTA High School Physics Examination

Section A. **Mechanics** (30%)
1. Motion in one dimension (5%)
2. motion in two dimensions (5%)
3. dynamics of a single body (5%)
4. mechanical energy (5%)
5. linear momentum (5%)
6. torque and rotation (1%)
7. law of gravitation and circular orbits (3%)
8. oscillations (1%)

Section B. **Waves, Optics, and Sound** (20%)
1. wave properties (6%)
2. geometric optics (7%)
3. physical optics (5%)
4. sound (2%)

Section C. **Heat and Kinetic Theory** (10%)
1. temperature and heat (4%)
2. kinetic theory of matter (4%)
3. thermodynamics (2%)

Section D. **Electricity and Magnetism** (25%)
1. electrostatics (7%)
2. direct-current circuits (6%)
3. alternating-current circuits (2%)
4. magnetism (5%)
5. electromagnetic induction (5%)

Section E. **Modern Physics** (15%)
1. atomic physics (7%)
2. nuclear physics (6%)
3. special relativity (2%)

Fig. 1. This distribution of topics for the examination represents the average teaching practice of members of the examination committee.

School, Houston, Texas, who was Bill Arnold's successor as NSTA High School Division Director, and Tim Ingoldsby. Subsequently, I was appointed Test Director and given responsibility of overseeing the development of the examination.

During the next two months 32 members of the committee submitted over 600 questions that were entered into the AAPT Word Processor at Stony Brook. (As a point of history, the first questions were submitted by Jim Vermillion from Merrilville, IN.) All the questions were reproduced on five by seven cards and sent to Stevens Point where 18 committee members worked in groups of three reviewing and rewriting questions (Fig. 2). As we debated style, level of difficulty, appropriateness, and validity of physics, we grew in our understanding not only of testing but also of teaching. Everyone who attended the Stevens Point writing session felt they had a significant educational experience, and many members of the committee requested edited copies of the questions they had submitted. I was extremely pleased with the cohesiveness, ability, and dedication of the group. This reviewing experience has led to the idea of conducting workshops on question development at the national meetings of AAPT. The first such workshop was presented at the 1981 meeting in New York City.

At Stevens Point we realized that we needed to determine the topic distribution, the method of scoring, and the final format of the examination. The topic distribution was settled by a questionnaire sent to committee members. The average response is shown in Fig. 1. I later met Will Pfeiffenberger, the Senior Examiner for Science at

Fig. 2. Mario Iona and Floyd Read reviewing questions.

Educational Testing Service (ETS), and found that our topic distribution did not differ markedly from the distribution used by ETS on the Physics Achievement Test. We also decided to base the score on the number of correct answers. Experience with the ACS/NSTA tests has shown that in a test designed to be completed by most students, deductions for incorrect responses do not significantly affect the standing of students.

After Stevens Point two trial versions of the examination containing 62 questions each were developed from the pool of edited questions. These trial versions were reviewed by the committee at the Spring 1982 NSTA meeting in Chicago. Members of the committee who were unable to attend the review meeting received the trial versions by mail. In the spring of 1982 the trial versions were field tested by about 2000 students from 50 schools in the United States and Canada. During the fall of 1982 the trial version results were submitted for an item analysis conducted by Ted Blew of ETS. The results of this analysis were used to select the 80 questions for the examination that will be available this spring. If you are interested in ordering a set of examinations, see page 137 of this issue of *The Physics Teacher*.

A major concern of the committee was to provide flexibility and to prevent the examination from becoming a *de facto* national curriculum. We feel strongly that physics at the high school level should be more concerned with quality than quantity, and that few teachers can cover or few students learn in one year all the topics generally presented in a high school physics textbook. To provide flexibility the examination is divided into five sections as follows:

	Part I		
Section	Topic	questions	minutes
A	Mechanics	24	27
B	Waves, Optics and Sound	16	18
		40	45
	Part II		
C	Heat and Kinetic theory	8	9
D	Electricity and Magnetism	20	23
E	Modern Physics	12	13
		40	45

Each section of the examination can be used separately or in any combination with other sections. AAPT will maintain norms by section and for the examination as a whole. We hope this will provide flexibility and still permit teachers to compare their students' achievement with a

A positively charged particle moving at a constant speed enters a uniform magnetic field. If the motion of the particle is parallel to the field lines, the particle will

A. experience no magnetic force.
B. follow a parabolic path.
C. experience a retarding magnetic force.
D. follow a circular path.
E. experience a magnetic force in the direction of the particle's motion.

Fig. 3. Example of a recall question.

national sample. Using the results returned from the use of the examination this spring, AAPT plans to develop norms for subgroups such as semesters of physics, semesters of mathematics, year in school, gender, textbook used, etc. For each group norms will be calculated showing percentile rank of a score. Percentage correct and correlation coefficients will be determined for each question. When this information is released, no reference will be made to individual students or schools.

We have also rated the questions into three categories:

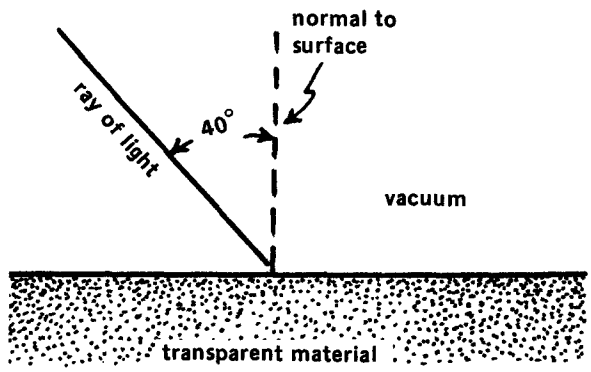
A. Recall questions . . . . . (25% of examination)
B. Standard or single concept questions . . . . . (50% of examination)
C. Complex or multiple concept questions . . . . . (25% of examination)

Figures 3 to 6 show examples of each question group, and demonstrate the style we have developed. In the recall question shown in Fig. 3, students only need to know that a perpendicular component of velocity is necessary for a magnetic force to act on a moving charged particle. Although the question in Fig. 4 requires a knowledge of both reflection and refraction, we judged it to be a standard question. Note that the need to use trigonometry and a calculator is avoided by giving a range of values in the choices rather than specific numerical results. Figure 5 shows a question that we rated as complex. This question can be solved using the concept of conservation of energy, but requires considerable thought. Figure 6 shows a question that covers many topics.

Many of the decisions made by the examination committee will not find universal acceptance. For example, the committee was split over the use of conventional current. The decision was made to use conventional current, but we made an effort to minimize the need to use conventional current by labeling power-supply terminals negative and positive. Each teacher who orders copies of the examination will be asked to complete a questionnaire so that future examinations will reflect the needs of teachers.

The High School Examination Development Committee was a temporary committee charged with developing a single examination. If this project proves to be successful and meets with the approval of AAPT and NSTA, additional versions will be developed on a periodic basis. In addition, other by-products of this project seem possible:

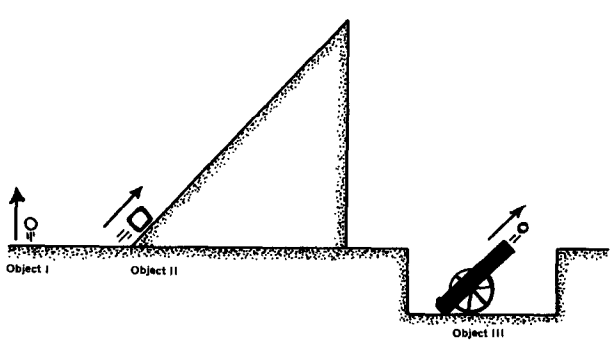
1. Exchanging questions with similar projects in other countries (e.g., see Ontario Assessment Instrument Pool.[1]



A ray of light, initially traveling in a vacuum, is incident on the surface of a flat transparent material as shown above. Part of the light is reflected and part is refracted. The angle between the **reflected** ray and the **refracted** ray is

A. less than 40°
B. between 40° and 50°
C. between 50° and 100°
D. between 100° and 140°
E. more than 140°

Fig. 4. Example of a standard question. The need to use trigonometry and a calculator is avoided by giving a range of values in the choices.



Compare the three objects shown above:

Object I — A ball is thrown vertically upward.
Object II — A block is sliding up a long inclined plane.
NOTE: The block does not reach the end of incline.
Object III — A ball is shot as a projectile at the same angle as the inclined plane.

Neglect all friction and assume all three objects have the same initial speed, height and mass. Which of the following statements is true?

A. Object I will go higher than the other two.
B. Object II will go higher than the other two.
C. Objects I and II will go to the same height and higher than object III.
D. Objects II and III will go to the same height and higher than object I.
E. All three objects will go to the same height.

Fig. 5. This question was rated as complex by the committee.

How many of the five quantities below can be measured in newtons?

1. momentum divided by time
2. pressure divided by area
3. power divided by velocity
4. kinetic energy divided by distance
5. electric field intensity multiplied by charge

A. one
B. two
C. three
D. four
E. five

Fig. 6. Example of a multiple-concept question.

2. Developing two levels of examinations: one level for physics students who have taken the usual introductory course, and another for advanced placement or second year students.
3. Developing a large computer-based pool of questions. This idea is presently being considered by AAPT.
4. Using the examination statistics to provide data for future physics education research.
5. Using microcomputers to develop, review, score and exchange questions.
6. Assisting in the maintenance of standard format for equations, units, etc.
7. Developing examinations with not only multiple-choice but also free-response questions.
8. Providing a frame of reference for inexperienced teachers.
9. Developing a "crib sheet" of formulas and constants to accompany the examination similar to the formula sheet used in conjunction with the New York Regents Examination.

Based on the large number of teachers who expressed interest in trying the trial version of the examination, my conversations with many teachers, and the small number of dated standardized physics tests available as reported by NSTA in the publication *Compendium of Standardized Science Tests,*[2] I believe that this committee has performed a much needed task, and that our efforts will result in materials that will be used by high school teachers and their students for years to come.

High School Physics Examination Development Committee

Frank Anderson, Jacksonville, FL
George Barrett, Buffalo Grove, IL
Bill Berner, Springfield, PA
Crispin Butler, Middlebury, VT
George Carr, Lowell, MA
Kailash Chandra, Savannah, GA
Gertrude Clarke, Whippany, NJ
Roger Daniels, San Antonio, TX
Claire Dewberry, Jacksonville, FL
Alex Domkowski, Knoxville, TN
Merle Erickson, St. Paul, MN
Robert Feldman, Flushing, NY
Thomas Fini, Amherst, NY
John FitzGibbons, Cazenovia, NY
Uri Ganiel, Rehovot, Israel
Robert Good, Swarthmore, PA
John Hamilton, Brunswick, GA
William Hardin, N. Easton, MA
Michael Holst, Alderwood Manor, WA
Frank Huss, Cincinnati, OH
Mario Iona, Denver, CO
Gerard Keena, Levittown, NY
Wesley Knapp, Scotia, NY
Bill Layton, Santa Monica, CA
Arvid Lonseth, Ashland, OR
Joan Mackin, Westgrove, PA
Patrick McNamara, Indiana, PA
Joseph Mosca, E. Williston, NY
Robert O'Connell, Dubuque, IA
Maria Pluta, Olympia Fields, IL
Charles Price, Evansville, IN
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Charles Reno, Euclid, OH
Lois Rynkiewicz, Danbury, CT
Meredith Schell, Ramsey, NJ
Glenn Schmucker, Indianapolis, IN
Douglas Smith, Rockford, IL
Andrew Stephanou, Australia
James Vermillion, Merrillville, IN
Michael Wade, LaGrange, IN
Malcolm Wells, Tempe, AZ
John Wiegers, University City, MO
Alexander Williamson, Houston, TX

Fig. 7. Members of the High School Physics Examination Development Committee

References

1. Ontario Assessment Instrument Pool
   The Minister of Education
   Toronto, Ontario, Canada M7A 1N8
2. *Compendium of Standardized Science Tests*
   National Science Teachers Association
   Washington, DC 20009

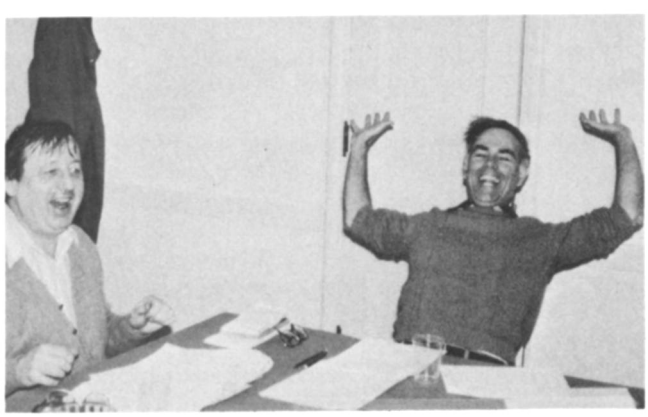

Fig. 8. John FitzGibbons and John Wiegers celebrate after completing the review of the last question.