Guidelines for High School Physics Programs

A publication of the
American Association of Physics Teachers

Editor's Note

At the request of the Section Representatives of the American Association of Physics Teachers (AAPT), a task force was established to develop the original guidelines for high school physics document. A preliminary draft was circulated within the physics teaching profession for evaluation and refinement. The Council of the American Association of Physics Teachers first adopted *AAPT Guidelines for High School Physics Programs* in 1984. Because the AAPT High School Committee has physics curriculum and instruction as its major concern, this committee completed the current revision of the guidelines in 2002.

The AAPT Committee on Physics in High Schools acknowledges and thanks the following AAPT members for their generous efforts in revising this document:

Beverly T. Cannon, *Dallas, TX*
Gene Ewald (Chair of AAPT High School Committee), *Cuyahoga Falls, OH*
Cathy Ezrailson, *The Woodlands, TX*
Jim Nelson, *Orlando, FL*
Rex Rice, *St. Louis, MO*
Judy Schmidt, *Franklin, WI*
Rosaline Secrest, *Terre Haute, IN*
Angelina Winborne, *Garrison, NY*

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AAPT Guidelines for High School Physics Programs

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AAPT Guidelines for High School Physics Programs

The American Association of Physics Teachers (AAPT) developed this document as a resource for high school administrators, parents, and teachers who are interested in developing guidelines for physics curriculum and instruction in their school(s). These guidelines reflect the goals of the AAPT, with an emphasis on instructional strategies and content appropriate for high school students. Every effort has been made to assure that these guidelines comport with statements and publications issued by the National Science Teachers Association (NSTA)[2] and the National Science Education Standards.[3]

Executive Summary

The professional preparation and the working condition of physics teachers significantly affect the quality of a high school physics program. Some factors that influence working conditions include:

- Administrative support;
- Appropriate budgets (e.g., annual, petty cash, repair, staff development, etc.);
- Appropriate facilities for classroom instruction and laboratory activities;
- Clearly articulated horizontal and vertical curriculum;
- Instructional materials (e.g., laboratory equipment, references, technology, textbook, etc.); and
- Opportunities for professional affiliation and growth.

While there is no complete definition of quality in describing a high school physics program, AAPT regards the following components to be essential for a strong physics program:

- ***Administrators*** who understand the unique needs of physics teachers and physics courses and who encourage the professional affiliation and growth of teachers in both physics content and pedagogy;
- ***Budget*** allocation that reflects the unique needs of a physics program;
- ***Curriculum*** that offers physics at several levels to meet the varying needs of students (e.g., Standard Physics, Honors Physics, Advanced Placement Physics, etc.);

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1 http://www.aspt.org

2 http://www.nsta.org

3 National Science Education Standards, 1996, National Research Council, ISBN 0-309-05326-9

- ***Instruction*** that provides opportunities for students to develop scientific knowledge and process skills through classroom demonstrations, discussion, inquiry, laboratory activities, research, special projects, testing, etc.;
- ***Resources*** (e.g., facilities, instructional materials, laboratory equipment and supplies, references, technology, etc.); and
- ***Teachers*** who are well prepared for teaching physics. Teachers with a strong content knowledge of physics and how physics integrates with other curricular content. Teachers with strong knowledge of instructional strategies. Teachers who receive and provide mentoring in pursuit of lifelong professional growth.

The following pages describe these six components in greater detail.

Administrative Support

School administrators are responsible for many of the working conditions that impact the quality of the physics program. These responsibilities include:

- the number and type of classes in a teacher's schedule;
- the number of students in each class; and
- the budget for instructional materials, laboratory equipment and supplies, petty cash, repair, and staff development.

The ability of the teacher to provide quality opportunities for students depends on the number of instructional minutes per day, the number of different preparations, and the number of students in a class.

Guideline 1: The Average Teaching Load Should be No More Than 275 Instructional Minutes Per Day with No More Than Three Different Preparations

In large schools a teacher might be responsible for physics all day. In small schools where several preparations are required of the teacher, the physics teacher should have a limit of only two science preparations. Any additional preparations should be in related areas such as computer science or mathematics. To be effective, a physics teacher must be able to devote sufficient time to maintaining the laboratory. This includes time to set up, repair, and put away laboratory equipment used by students to do laboratory activities. Additional time is required for preparing demonstrations, maintaining laboratory equipment, and correcting student work (e.g., homework, laboratory reports, projects, tests, etc.)

Guideline 2: The Maximum Student Load Should Depend on the Number of Teacher Preparations

The teacher with laboratory preparation and evaluation cannot do an adequate job of teaching and evaluating students if required to teach more than 125 students in a day. This number should be reduced considerably if the laboratory activities are diverse in makeup. For example, if 125 were an appropriate number of students for a teacher who devotes the entire day to teaching physics, 100 would be reasonable if this same teacher is responsible for both physics and chemistry classes. Supervision of student research projects and other science activities should be considered in assigning the overall student load.

Guideline 3: The Number of Students Per Class Should Not Exceed the Number of Laboratory Stations

The optimum size of a physics class depends as much on facilities and safety as on the workload of the teacher. Every high school physics class should have an absolute limit that is determined by the number of laboratory stations and the design of the room(s) where the physics classes meet. The conventional limit is 24 student stations. Other limiting factors for laboratory class size are the effective supervision of the students in laboratory procedures and strict monitoring of safety practices.

Guideline 4: The Additional Task of Maintaining the Laboratory Equipment and Facilities Should be Interpreted as Equivalent to One Class Period

The laboratory represents the equivalent of another preparation or extracurricular assignment. Laboratory sessions require time for setting up and taking down laboratory equipment, checking procedures, keeping inventory, and grading student laboratory reports. Laboratory equipment also requires maintenance and repair. Setup and maintenance time increases with the presence of high-tech laboratory equipment. It should be pointed out that teachers must perform most laboratory responsibilities at the school site. The responsibilities and requirements of the physics teacher should be considered in assigning teacher loads and extracurricular duties.

Guideline 5: The School Should Employ a Laboratory Technician and/or Secure Student Help to Extend the Effectiveness of the Physics Teacher Where Laboratory Preparation and Maintenance Is Not Considered Equivalent to One Class Period

A laboratory technician is defined as any paraprofessional assistant employed to work with the physics teacher and could include secretarial aides and laboratory aides. Every effort should be made by the school to employ paraprofessional personnel and/or student help to assist the teacher in preparing classroom and laboratory experiences. An effective way of supporting an active laboratory and project-oriented physics program is through the use of student assistants. Students who would otherwise be in a study hall can contribute markedly to a science program and in turn benefit from continued exposure to one of the sciences. In some schools students can earn community service hours for assisting in the classroom. Duties of these assistants could include setting up and taking down laboratory equipment, maintaining and inventorying the storeroom, and making minor repairs on laboratory equipment.

A school system concerned with maintaining a quality physics program should provide paid opportunities for their physics teacher(s) to update and revise the curriculum, repair laboratory equipment, construct laboratory equipment, design and maintain a laboratory inventory system, and prepare new physics teaching materials. These tasks require a great deal of time often not available during the academic year to the physics teacher who teaches a full class load and sponsors extracurricular activities. Paraprofessional personnel could be employed during the summer to assist the physics teacher in developing and producing teaching materials.

Budgetary Support

Guideline 1: The Physics Program Should be Given an Adequate Budget for Laboratory Equipment

In most states physics is a laboratory course. Without extensive laboratory experiences, learning is inadequate and incomplete. The school system needs to provide an adequate budget for purchasing laboratory equipment for ongoing laboratory activities and projects, for maintaining physics laboratory equipment, and to update and improve facilities. The number of pieces of laboratory equipment should be equal to the number of laboratory stations used by students. In a typical physics classroom, this is between six and 10 laboratory stations each designed to accommodate two to four students. The recommended annual budget for equipment is $1 per week per student. For a student load of 125 students, this is about $4,500 per year. There should be a separate line item for new laboratory equipment purchases in the school budget. Fortunately physics equipment typically lasts for several years, and the cost can be amortized over an extended period.

The typical startup cost for a new school is about five times the annual budget mentioned above. A starting point for a completely unequipped or new physics classroom/laboratory can be obtained by matching your curriculum with science catalogs that give a list and cost of basic laboratory equipment. Often teacher editions of physics laboratory manuals have a listing of required laboratory equipment and supplies. Many states have science consultants to assist in setting up new laboratories. Basic laboratory equipment should be included in the first year's budget.

Guideline 2: The Minimum Budget for Laboratory Supplies Should be Based on the Student Enrollment

After the basic laboratory equipment is in place, the budget for supplies should be reviewed annually. AAPT suggests establishing a minimum budget for a physics program, for example, 50 cents per week per student for annual materials. Thus for a teacher with a load of 125 students, a laboratory supply budget would be $2,250 per year per teacher. The cost of a student text is about $60. A laboratory manual and notebook cost an additional $45. AAPT believes that the experiences in the laboratory are essential and thus worth the additional expenditure.

Guideline 3: Administrators and Teachers Should Work Together to Set Budget Priorities

The physics teacher should review the budget items with the administrator responsible for budget procedures in the school. This would ensure that the teacher would receive those supplies that are absolutely required for teaching the laboratory course. In addition, the teacher can better plan the laboratory experiences knowing the necessary materials will be available.

Guideline 4: The Budget Priorities Should be Modified with the Cooperation of the Physics Teacher

Modification of the budget with the cooperation of the teacher ensures that the administration and the teacher understand the consequences of deleting items. An expensive piece of laboratory equipment may be rendered useless if requested replacement parts or auxiliary laboratory equipment necessary for operation are deleted.

Guideline 5: A Petty Cash Budget for Local Purchases Should be Established

Many items used during laboratory activities (e.g., aluminum foil, batteries, fuses, film, string, etc.) can be purchased locally when needed and at a reduced cost. A procedure should be put in place to see that funds for local purchases are properly monitored and used in a responsible way. Funds for local purchases should be a part of the science budget with assurance that the teacher is reimbursed for authorized petty cash purchases.

Guideline 6: It Is Appropriate to Provide a Budget to Maintain Laboratory Equipment in Good Working Order

Physics teachers should take all possible steps (e.g., maintain an inventory of laboratory equipment, monitor students' treatment of equipment, remove batteries when laboratory equipment is stored, cover expensive equipment such as computers when not in use, store equipment in original containers, etc.) to keep the laboratory equipment in good working order. It must be recognized that some breakage is bound to occur. Funds to repair broken equipment should be a part of the school's annual science budget. It is bad business to allow an electronic balance to sit unused on a shelf because the budget did not cover repairs.

Curriculum

Guideline 1: Within a School There Should be a Variety of Physics-Related Courses that Appeal to Students of All Abilities and Serve All Students' Needs

AAPT believes that all students should take a physics course in high school. Physics is the basic science. Our society is becoming more dependent on technology rooted in physics. Thus every high school has an obligation to offer at least one broadly appealing physics course that is open to all students and that will result in a better informed citizenry. Physics, along with biology and chemistry, provide science courses that ensure a broad-based science background. It is not necessary for this physics course to be based upon advanced mathematics. A laboratory and project-based conceptual course would encourage a larger percentage of students to take physics.

In many schools today physics is offered only after students have completed a biology and a chemistry course; however, there is a growing trend in the United States to offer physics as the first high school science course followed by chemistry, biology, and earth science.

A second physics course is recommended for the highly motivated and/or well prepared students who intend to pursue a science-related curriculum in college (e.g., engineering, medicine, etc.). This course provides an opportunity for collaboration with a supporting mathematics program by employing a strong mathematics and problem-solving approach.

Advanced placement courses provide for those students who are interested in gaining college credit while still in high school or who plan to pursue college courses that build on advanced physics work in high school.

Guideline 2: The Teacher Should Share the Responsibility for Aligning Curriculum Within the School and with State and National Science Standards

The physics teacher should take a leadership role in developing horizontal and vertical articulation within the school system and in developing and/or selecting curricular materials and approaches. Teacher skills, curricular materials, instructional approaches, and laboratory equipment must be kept up-to-date. All aspects of the physics program should be reviewed and evaluated at least every five years. Teachers should review materials with an awareness of national physics curriculum programs and publications of AAPT. Each of these

resources contributes unique features to the teaching and learning processes of high school students. Teaching techniques and learning theories should be reviewed periodically. Teachers should be involved in the planning and execution of staff development. By being a member of professional societies and receiving such publications as *The Physics Teacher* of the American Association of Physics Teachers or *The Science Teacher* of the National Science Teachers Association, the physics teacher will be informed of the latest curriculum developments, teaching procedures, teaching materials, texts, and laboratory equipment. Schools should see that professional journals are placed in their school libraries for use by both students and teachers. AAPT, through the PTRA (Physics Teaching Resource Agents) Program, has developed many workshops that respond to new curriculum changes encountered by the physics teacher and learning strategies that meet the needs of the student learner. Information about PTRA workshops can be obtained from the PTRA website, www.aapt.org/ptra/ or by calling the AAPT Programs Department at 301-209-3344 or by sending e-mail to aapt-prog@aapt.org.

Classroom Activities and Instruction

Guideline 1: Effective Physics Teaching Includes Laboratory Activities as an Integral Part of Classroom Instruction

The physics program should have students engaging in classroom and laboratory activities that involve the processes of science, employing an inquiry approach. These activities involve groups of students working together to solve a problem (e.g., What makes an effective amusement park ride? How can human hearing be protected?, etc.), measure an important value (e.g., acceleration due to gravity, focal length of a lens), or find a relationship among variables (relationship between length of pendulum and the period, relationship between voltage and current, etc.). A concise explanation of comments and rational for this laboratory approach to learning is discussed further in an AAPT position paper, *The Role of Laboratory Activities in High School Physics*.[4]

AAPT recommends that 40 percent[5] of class time be devoted to laboratory activities. Experienced physics teachers point out that some topics (e.g., motion, behavior of light, etc.) lend themselves more easily to extensive laboratory activities, while other topics (e.g., nuclear reactions, Kepler's laws, etc.) are more difficult to include in laboratory activities. However, on average about 40 percent of class time should be devoted to laboratory activities. When laboratory activities are difficult to do, teachers often use simulations to help students gain an understanding of a topic. Laboratory activities and simulations are a critical part of an effective science program. This instructional need should also be considered when assigning teacher workload.

Guideline 2: Effective Physics Teaching Includes Interactive Demonstrations

The use of interactive demonstrations by the classroom teacher is an effective way to engage the learner. Performing demonstrations requires additional planning, preparation, and cleanup time. This instructional technique should also be considered when teacher workloads are assigned.

Guideline 3: Effective Physics Teaching Includes Opportunities for Students to Make Presentations to Classmates on Topics Being Studied

The physics program should have students engaged in making classroom presentations to other students. This can be done in a variety of ways; however, the use of whiteboards and markers is a convenient and common method. This not only enhances the student's knowledge of physics and scientific reasoning, but also enhances the student's confidence as a speaker.

[4] http:www.aapt.org/policy

[5] http://www.nap.edu/readingroom/books/nses/html/7.html#spf

Resources

Guideline 1: Adequate Classroom and Laboratory Space Should be Available for Planning, Preparing, Instruction, and Special Projects

Since effective high school physics learning requires active participation in laboratory activities to support classroom instruction, laboratory facilities are essential. In some schools the laboratory is part of the regular classroom, and in some schools it is a separate room. In either case, the size of the physics laboratory must be large enough so that all students can participate in real, hands-on laboratory activities. There should be adequate ceiling height and means for hanging laboratory equipment (e.g., pendulums, Slinky, etc.). Most physics experiments require a movable table with a flat surface clear of obstructions (no fittings are needed). Sinks, water, gas, and electricity should be provided safely and convenient to the tables (e.g., around the perimeter of the room). Adequate lighting with light-dimming capabilities should be available. The ability to darken the laboratory thoroughly is required for most optics laboratory activities.

Safety equipment should include items such as a fire blanket, fire extinguisher, safety goggles, and any other safety equipment required by local codes. This might be very important if physical science is to be taught in the same laboratory. Safety procedure checklists should be developed for the physics laboratory. Safety checks should include electrical equipment, suspension systems, lasers, radioactive sources, radiation-monitoring equipment, etc. There should be a maximum of one year between safety checks. This is often done at the beginning or end of the school year.

Guideline 2: Special Space Must be Provided for Use as Stockroom, for Preparation Room, and for Projects

Adequate storage space must be available for laboratory equipment and materials. The storage space with cabinets and shelves of various sizes is essential to accommodate the variety of laboratory equipment used in a physics program. Basic tools (e.g., drill, hammer, pliers, screw drivers, soldering iron, etc.) should be available and maintained. Essential supplies should be kept in stock. Adequate storage prevents unnecessary breakage or loss of laboratory equipment and allows immediate accessibility. If special student projects are encouraged, space to store and work on projects should be provided. Adequate workspace must be available for both teacher and students.

Guideline 3: Classrooms Must Contain Physical Laboratory Equipment that Allows the Teacher to Utilize Multiple Representations of Ideas and Concepts

More and more resources are being developed to illustrate physical science ideas. Dynamic videos of molecular motion, wave motion, etc. are being introduced almost daily. To take advantage of these developments, the physics classroom and associated areas should have full audio-visual capabilities. Many audio-visual materials such as, but not limited to, CD-ROM, computer projection, digital camera, DVD, Internet access, VCR, and video camera are increasingly becoming an integral part of the teaching-learning process. These resources should be reasonably close to the classroom. Adequate chalkboard/whiteboard space and bulletin board space should be available. In addition, there should be provisions to present physics demonstrations clearly and safely to all students in the classroom.

Guideline 4: Appropriate Laboratory Equipment Should be Available for Effective Instruction Based on Active Student Engagement

Appropriate laboratory equipment is essential for teaching and learning physics. The opportunity for active student engagement with laboratory equipment in a laboratory or experimental setting should reflect the curriculum. Examples of active student engagement include using computers to gather and analyze data, using standard measuring devices (e.g., electronic balance, force meter, graduated cylinder, protractor, voltmeter, etc.), using ripple tanks to illustrate wave phenomena, using a photogate to time the motion of a pendulum, etc.

Guideline 5: High School Physics Classrooms and Libraries Should Have Many of the Following Reference Materials that Have Been Developed for Physics Teachers

Printed Materials for Teachers:

- "A Survey of High School Physics Texts," Clifford Swartz, *Phys. Teach.*, **37** 283 (May 1999).
- *Demonstration Handbook for Physics*, Freer & Anderson (AAPT)
- *Products Catalog* (AAPT)
- *Resource Kit for the New Physics Teacher* (AAPT); out of print; revision available after 2003
- *Safety in Physics Education* (AAPT)
- *Teaching Introductory Physics*, Arnold B. Aarons (AAPT)
- *The Physics Teacher* (monthly publication – AAPT)
- *The Science Teacher* (monthly publication – NSTA)

Video Resources:

- 3000 Physics Demonstrations[6]
- Mechanical Universe Video[7]
- Physics Cinema Classics[8]

Physics Software:

- C^3P (Comprehensive Conceptual Curriculum for Physics)[9]
- CPU (Constructing Physics Understanding)[10]
- Physics Academic Software[11]
- Physics Info Mall[12]

Electronic Resources for Teachers:

- American Association of Physics Teachers (AAPT[13]) website at http://www.aapt.org
- American Institute of Physics website at http://www.aip.org
- Physical Sciences Resource Center (PSRC[14]) website at http://www.aapt.org/psrc
- Physics Central website at http://www.physicscentral.org

Guideline 6: High School Physics Classrooms and Libraries Should Have Many of the Following Reference Materials that Have Been Developed for Physics Students

Printed Materials for Students:

- *Discover* (Monthly Publication)
- *Quantum* (Although no longer available, back copies are of interest.)
- *Science* (Monthly Publication)
- *Scientific American* (Monthly Publication)

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[6] http://www.physicsdemos.com/HTML/mainpage.html

[7] http://www.learner.org/resources/resource.html?uid=42&sj=; also available from AAPT at http://www.aapt.org/store

[8] http://www.ztek.com; also available from AAPT at http://www.aapt.org/store

[9] http://phys.udallas.edu

[10] http://cpuproject.sdsu.edu/CPU/

[11] http://webassign.net/pasnew/aboutpas.html

[12] http://learningteam.org/infomall.htm

[13] AAPT is the largest physics teacher professional organization in the world and supports a large number of products, services, and activities that are available to physics teachers. Some of the many AAPT services and activities include Free High School Physics Certificates, Physics Bowl Contest, Physics Olympiad, PTRA workshops, Student Photography Contest, Teacher Grants, etc.

[14] PSRC contains a vast number of resources that are of use to physics teachers at http://www.aapt.org/psrc

Physics Software:

- CPU (Constructing Physics Understanding)
- LOGAL Software
- Physics Academic Software
- Physics Info Mall

Electronic Sources for Students:

- *Discover* magazine online at http://www.discover.com
- New journal of physics online at http://www.physicsweb.org
- *Scientific American* online at http://www.sciam.com

Guideline 7: A Reasonable Attempt Should be Made to Keep Up with Rapidly Changing Technology

In order to reflect the real world use of computers in science and industry, schools should be encouraged to implement electronic data acquisition, electronic data analysis, computer simulation/modeling, and other newly developed technologies that a teacher believes are important and appropriate. Electronic laboratory equipment should be kept in repair, and nonrepairable items should be replaced as needed.

Teachers

Guideline 1: Physics Teachers Should Have a Strong Content Knowledge

Teachers who are responsible for teaching physics should be well grounded in physics content, in the relationship of physics to other content areas, and in instructional strategies. AAPT recommends that high school physics teachers have the equivalent of 24 semester hours of physics including the study of:

- **Electricity and Magnetism**
- **Mechanics (Force & Motion)**
- **Nuclcar Physics**
- **Thermodynamics**
- **Waves, Sound and Optics**

Guideline 2: To Ensure Teacher Professional Growth in Both Content and Pedagogy, an Extensive Staff Development Program Must be in Place

Teachers need professional affiliations to continue to grow throughout their teaching career. This need can be met by attending classes, workshops, and professional meetings.

Teachers need support in maintaining and developing new programs and procedures. Teachers with a variety of backgrounds, new teachers, teachers from other disciplines, as well as master teachers, need both an extensive staff development program and administrative support. Special training is required for initiation and implementation of specific physics programs such as Active Physics,[15] C^3P,[16] CPU,[17] Modeling,[18] PhysLab,[19] PRISMS (Physics Resources and Instructional Strategies for Motivating Students),[20] and others. Interactive technologies, including the computer, graphing calculator, data acquisition devices, multimedia and the Internet, introduce additional areas for training and curriculum development. Physics Teaching Resource Agents (PTRA) have been trained and certified by AAPT to serve as leaders of workshops in areas

[15] http://www.its-about-time.com/htmls/ap.html
[16] http://phys.udallas.edu/
[17] http://cpuproject.sdsu.edu/CPU/
[18] http://modeling.asu.edu/
[19] http://charlotte.gunn.palo-alto.ca.us/~cbakken/physlab/
[20] http://www.prisms.uni.edu/

that improve teaching skills and content knowledge. For the names and contact information of PTRAs in your area, visit the PTRA website at www.aapt.org/ptra/. Some other means of staff development include attending AAPT, NSTA, and other professional organizational conferences, participating in state and local organizations/alliances,[21] and taking web courses.

Guideline 3: Budget Provisions Must be Available for Professional Growth

Professional growth is of supreme importance. The teacher must be given time off and financial support to participate in content or pedagogical programs and to attend professional conferences. This is imperative in schools where physics teachers are often isolated from other professional physicists and physics teachers. To keep abreast of the rapid changes in physics and physics education, teachers must have the opportunity to attend professional meetings. This includes national, regional, and local meetings and workshops. Physics teachers should be encouraged to form local alliances or attend local AAPT Section meetings for the purpose of exchanging ideas, implementing programs, and designing new materials. If the teacher wants to use classroom or laboratory facilities for meetings or workshops during nonschool hours, the school system should make this space available.

[21] *The Physics Alliances Newsletter*; http://www.aapt.org/psrc; then click on Teaching Communities

Other titles in the AAPT Guideline series:

- ***Guidelines for Two-Year College Physics Programs***
- ***Planning for Graduate Studies in Physics and Related Fields***