PHYSICS FIRST

Building a stronger foundation in the knowledge and understanding of science

Opening Minds, Opening Doors
75 Years of Excellence
1931 2006

American Association of Physics Teachers

Physics First

An Informational Guide for Teachers, School Administrators, Parents, Scientists, and the Public

Sponsored by the High School Committee of the
American Association of Physics Teachers

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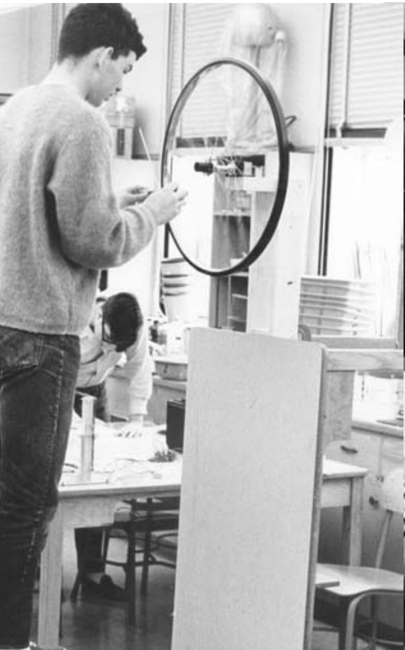
INTRODUCTION

Are you looking for ways to help high school students build a stronger foundation in scientific knowledge and understanding? Are you willing to take risks and try new, innovative ideas in your science classroom? Do you wish more students could be exposed to the joy of learning physics? If these ideas resonate with you, you might just be interested in looking at Physics First.

Physics First is much more than just teaching physics to younger students; it represents an organizational alternative to the traditional high school science sequence.

The purpose of this pamphlet is to provide:

- basic information and rationale for the Physics First curriculum,
- strategies for implementing Physics First in your school,
- suggestions for avoiding pitfalls, and
- additional information, references, and resources for Physics First.



What Is Physics First?

Physics First calls for a re-sequencing of high school courses so that students study physics before chemistry and biology.

There are many historical events that have led to the current common practice in the United States of teaching physics to students after they have taken biology and chemistry. While the story as to how this sequence developed is interesting, the important point is: with this sequence, only 30% of U.S. high school students take any course in physics. The wisdom of placing physics last is being reconsidered by educators because 1) in order to understand modern molecular biology and the biochemical processes in cells, students need a solid background in both physics and chemistry, and 2) mastery of the basic physics concept of electrostatic and nuclear forces and the concept of energy storage and transfer are crucial to the understanding of chemical structures, atomic binding, gas laws, and the periodic table of the elements.

The National Science Foundation (NSF) and many other public policy groups have established the goals of promoting a science-literate citizenry and encouraging more students to consider careers in science, engineering, and mathematics. Placing physics first would expose more students (not only the current 30%) to the discipline that provides the foundation for understanding engineering concepts and provides real-world connections to mathematical concepts.

About This Pamphlet

The AAPT High School committee requested the development of this informational pamphlet for Physics First.

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Exposing most students to physics at the appropriate time and at the most appropriate level will allow more students the opportunity to develop interests and make the choice of a profession that relies on science, engineering, or mathematics. Observations of the performance of U.S. students on tests comparing them with non-U.S. students indicate that our competitive edge may be slipping. In his book *The World Is Flat: A Brief History of the 21st Century*, Thomas Friedman adds to the cacophony of voices warning that America is in the midst of a "quiet" crisis. "We are not producing, in this country, in America, enough young people going into science, technology, and engineering—the fields that are going to be essential for entrepreneurship and innovation in the 21st century."

Furthermore, the American Association of Physics Teachers (AAPT) recognizes that the Physics First approach has the potential to provide students with a solid intellectual foundation for the study of chemistry and biology later in their high school education as well as to increase the coherency of the secondary school science curriculum.[1]

Advocacy for the change to the Physics First approach has developed out of research in physics education that has identified problems with teaching physics last in the high school science sequence. One strong voice for changing the science sequence in U.S. high schools has been that of Leon Lederman, Nobel Laureate and former Fermilab director. Similarly, the Project ARISE (American Renaissance in Science Education[2]) advocates a three-year, coordinated science sequence that begins with physics, then chemistry, then biology while integrating earth science and astronomy topics into these areas.

What changes occur when physics is taught as the first science course for high school students?

In a beginning course in physics, students explore their own notions about common, everyday phenomena, discuss their observations with peers, and draw conclusions that can be tested. They begin to make predictions, practice data collection and graphing techniques, apply some mathematical skills to real situations, and start to make sense of their observations. Exposing a greater number of students to the concrete concepts of physics can provide the basis for understanding the more abstract concepts introduced in chemistry and biology.

The emphasis in a physics-first sequence should be focused on conceptual understanding rather than mathematical manipulation. This does not preclude a mathematical approach for the advanced students. Physics in ninth grade will parallel the goals of basic algebra: reinforcing skills such as solving equations, interpreting graphs, and reasoning proportionately. The fundamentals of physics can be taught without a great deal of higher mathematics. All necessary mathematics can easily be introduced on a "need-to-know" basis.

The maturity level and cognitive development of typical ninth-grade students require adjustments in the approach to teaching the concepts. Ninth graders are more likely to be "concrete thinkers" and physics is more concrete than either chemistry or biology. Ninth-grade physics classes should also be less teacher-centered and should use inquiry labs to explore new ideas, allowing students to learn by doing rather than by reading or being told. Student misconceptions can be addressed and corrected before they become entrenched and harder to shed.

Characteristics of schools currently implementing Physics First

Responses to a 2005 survey conducted by the American Institute of Physics show that Physics First has been adopted at 9% of private schools and 3% of public schools in the United States (data solicited from teachers who are currently teaching physics as a first course). In the schools that claim Physics First, 44% of the public schools and 70% of the private schools have also switched to the Physics-Chemistry-Biology sequence. Much of the information about these schools is anecdotal at this point with little hard data to evaluate the effectiveness of Physics First. There is no one way in which schools are approaching Physics First; some offer a conceptual approach only, while many others offer two levels of introductory physics based on mathematical fluency of the students. Some follow an inverted sequence offering Physics-Chemistry-Biology while others start with physics but then allow a choice of the courses to follow.

There are a variety of programs and textbooks now suitable for a ninth-grade physics course. Some of these texts teach the mathematics on a need-to-know basis, including material on solving equations, thinking proportionately, and interpreting graphs of laboratory data. These texts are often accompanied by lab manuals and teacher's guides, allowing teachers the benefit of research into how younger minds best learn physics; again by doing rather than by being told. Some teachers prefer to modify their current curriculum materials to meet the needs of younger students.

In 2001, Project ARISE issued a report of a research project conducted by Spencer Pasero on the state of Physics First programs.[3] Fifty-eight public and private schools were studied. The schools that responded were all teaching physics as the first course and most have reported that this inverted sequence has been successful. Since this study, several large urban public school districts have joined the larger number of private schools by offering physics first and the institutions have met with mixed reviews.

What curriculum should be included in a Physics First approach?

If the sequence of instruction is being offered so that physics provides a foundation for chemistry or biology, the emphasis on topics might vary slightly from those used when the approach is designed to develop conceptual and mathematical understanding concurrently. So, the answer to this question requires that the goal of switching to Physics First has been clearly identified.

Possible topics for Physics First might include vectors, kinematics, dynamics, work and energy, momentum and collisions, circular motion, electric forces, electric potential, magnetism, electromagnetic waves, geometric optics, vibrations and waves, relativity, photons, quantum mechanics, and atomic structure. Few schools that are offering physics as a first course are able to include all of these topics in their curriculum. Most Physics First schools list motion, energy, Newton's Laws and forces, optics, sound and wave motion, and electricity and magnetism as the topics that are included in a basic physics curriculum. And these topics are typically determined by the type of mandated high-stakes state testing used to assess student performance. Although there does not appear to be a common approach to what topics are included, all schools share the goal of providing a strong foundation for further study in the sciences.

Experiences reported from Physics First schools

Teachers report positive experiences with the Physics First approach when they have had significant input in the decision and planning for the approach. Some of the positive comments:

- Students who take physics first often take more science courses in high school.
- Misconceptions are not as developed in ninth graders as they are by the time students reach 11th or 12th grade, and those misconceptions are easier to change with early physics instruction.
- Younger students are eager to explore and learn.
- The upper-level class (second-year physics course) can be more rigorous because students have a good foundation on which to build.
- Early adolescents can be successful learning algebra and physics concurrently (especially when the science and math departments work closely together) and reach a conceptual understanding of the physical laws.

In considering the change to Physics First, there are issues that must be understood and strategies that must be developed for the approach to be successful. These issues fall into four major categories:

1. Support

The stakeholders (teachers, administrators, guidance counselors, parents, and students) must see value in the change to Physics First. The support mechanism for teachers to implement this change should provide time for: a) planning, b) developing the pedagogical shift in teaching strategies to address the cognitive needs of younger learners, and c) strengthening content knowledge for science teachers not trained in physics. Justification for the change should be clearly conveyed to parents and students as well as other educators.

2. Staffing

If the decision is made to require physics of all ninth graders, there will be a need to increase the number of teachers whose primary teaching assignment will be physics. Teachers who have taught other areas of science may be reassigned to physics during the first few years of Physics First to meet the increased number of students taking physics. Consideration must be given to providing staff development for teachers who express a need to improve their content knowledge in physics.

3. Funding

Classrooms will need to be equipped for physics laboratory experiments. This is a critical step, as the success or failure of the physics course is often determined by the quality of the laboratory experience of the students. The number of students taking physics

Implementation suggestions

- ***Evaluate the overall philosophy*** of the school about science education. Do your teachers feel that it is more important to teach vocabulary, formula manipulation, and factual information, or to emphasize scientific thinking, reasoning skills, and experimental design? Get consensus among faculty and administration to support the change, especially those who will teach the class. The faculty who teach the course should believe in its merit and agree on the methods of instruction. Trying to force a ninth-grade physics course on teachers who don't believe that students will benefit from this approach will make its success that much more difficult.
- ***Decide whether to invert and integrate*** the entire introductory science sequence (biology, chemistry, and physics), require physics for all students, or put physics first and allow students to select their own sequence. Decide if the change will be an abrupt switch or a gradual one done over three or four years.
- ***Provide training*** for those who have never taught physics or ninth graders. This should be structured to identify areas of both content knowledge and pedagogical approaches that are needed for the success of this approach. For any new science program to be successful, the teacher must have a positive attitude, must like teaching younger students, must know physics well, and must understand the most appropriate pedagogical approach to meet the needs of these students.
- ***Make presentations*** to parents, administration, guidance counselors and faculty to educate as to the reason for change.
- ***Read as much of the literature on reform initiatives*** as possible as you plan the curriculum. Subscribe to AAPT's Physics First listserv (http://www.aapt.org/Membership/listservs.cfm) and check the physics first webpage (http://members.aol.com/physicsfirst/) often for updated information and links.
- ***Work with middle school*** math and science teachers to help them understand the change and solicit their help in preparing your future students.
- ***Formalize the experimental change*** by collecting data that will help assess the success of the approach. Allow adequate time to see what the data suggest. Too much of the current data is anecdotal at best and is strongly influenced by the attitudes of those providing the data rather than by actual scientific data (such as student performance in science and math in the 10-12th grades as well as PSAT scores before and after the change to Physics First). Decide what evidence would convince anyone that this change produces students who are more scientifically literate than those produced by the current approaches and develop a plan to collect and analyze those data.