



Sequencing the Upper School Science and Math Curriculum

Why Placing an Introductory Physics Class in Ninth Grade is a Great Idea (and Other Considerations)

John D. Mays

Every school has its own set of circumstances driving the science and math programming. But even though every school is different, some course sequences have many advantages over others. In this article we will take an in-depth look at the major considerations that should drive the science and math programming in high school and middle school.

Putting Physics First

For several reasons physics is the best choice for the freshman science for all students. This claim is frequently surprising, especially to educators more familiar with the Biology–Chemistry–Physics sequence. We will unpack it as we go along.

When discussing where to place physics in the high school program, it is important to keep in mind the distinction between an introductory physics course, which does not use vector computation methods, and

a more advanced course that incorporates vector methods into problem solutions. I will refer to these two courses as the introductory course and the vector/trig course. One of our objectives will be a program that gives all students a solid introduction to physics. Physics should not be just for the top students. On the other hand, for students of average ability to take physics they will need to take it at the introductory level. Vector/trig physics is very difficult and is not for everyone. I say this knowing full well what some states are doing with their state standards for science—insisting that all students take a vector methods course. As an educator who has taught physics for 17 years in public schools, private schools, and colleges, I can attest that this is utter madness. Private schools should consider carefully whether they will follow the public schools off the cliff or end the madness by adopting sensible, logical programming that can serve the needs of all students.

Some schools like to offer even more

advanced physics courses such as one or both of the College Board's AP Physics courses. Still other schools have developed integrated physics/calculus courses for top students. I do not propose to address these advanced AP courses or integrated courses here. Relatively few students are up for such advanced courses in high school, and relatively few Christian schools incorporate such courses into their program. Many schools have discovered that they can offer a robust program that prepares students for college well, and place those students into select colleges, without the complications that come with the AP and integrated courses. For those schools that do incorporate such courses into their program, I say more power to you. But the program we review here will serve most schools very well.

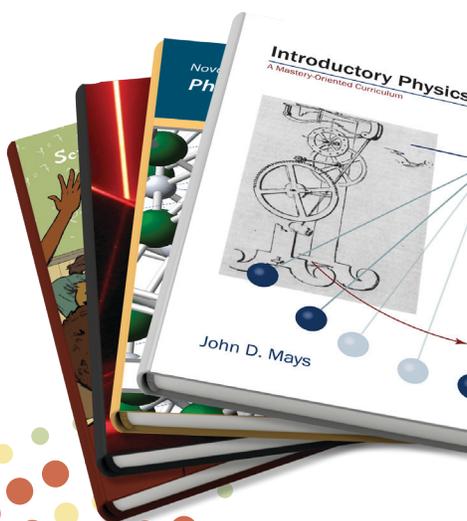
To begin, consider the options for placing physics in the high school curriculum. There are essentially three options. First, offer only vector/trig physics to upper level students (juniors or seniors). This is the way it was when I was in high school. The problem with this option is that only a small percentage of a typical student body can handle a course like this. When the vector/trig course is offered as an elective to upper level students, typically about 10–20% of the students will elect to take it, and those who do take it will have their work cut out for them. But if the vector/trig elective is all there is, some 80–90% of the students will not have an introductory physics course in high school at all, which means probably no physics course ever. This is not an acceptable scenario.

The second option is gaining in popularity because of the pressure of the new state standards in science. This option is to require all students to take a vector/trig



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continued on page 2

physics course during their junior year, offering a more robust course (such as an AP course) as an elective in the senior year. This is the madness option. As I wrote above, less than a quarter of a typical student body can handle a vector/trig course, even if it is watered down. From my own classroom observations—which includes very large, prestigious private schools (over 500 high school students)—I have concluded that this approach is an unmitigated disaster. When the class average on an exam in April is 63, and students are making pitiable jokes about their scores in the 40s (actual example), you know that the educational process has been reduced to farce. Despite the kooky pressure from the public schools, this option is really not an option. Vector/trig physics is not for everyone.

The third option is to teach introductory physics to all freshmen, and then offer vector/trig physics as an elective for upper level students (along with other upper level science electives). This option works very well, and appropriately addresses the needs of all students. Grade-level freshmen should take an introductory course that focuses on the basic principles of physics. The course should incorporate plenty of mathematics, but restrict the math to what students in first-year Algebra or Geometry can handle. The mathematics component is very important, and for this reason I do not recommend offering so-called “conceptual physics” to these students. Even students with modest ability can solve basic problems in motion, force, energy, density and so on, and such computations should definitely be part of the introductory course. The introductory course for accelerated or honors-level students should incorporate introductory chemistry as well.

I have been speaking of two different groups of freshmen: grade-level students who should take introductory physics, and accelerated students who should take introductory physics and chemistry. The assumption here is that your program is stratified into two different pathways (aka, tracks): a grade-level pathway and an accelerated pathway. I will address this issue briefly in the next section.

So far we have seen that placing introductory physics in the freshman year provides all students with an introduction to the subject, while allowing for higher-aptitude students to take a more advanced vector/trig course later as an elective. This argument for course placement is based

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on the practical but paramount concerns of student aptitude and appropriate placement. But another justification for placing introductory physics in 9th grade is the educational benefit of having a background in physics prior to taking chemistry or biology. The introductory physics course curriculum will include a number of topics important for chemistry such as energy, heat, energy transfer, phases of matter, electrostatic attraction, temperature scales, light, types of substances, and the internal structure of the atom. Covering these topics in introductory physics as freshmen will pay large dividends when students encounter them later in chemistry.

A solid introductory physics course should also provide students with a significant amount of practice in basic scientific mathematical skills. Two skills of supreme importance in science are performing unit conversions and using scientific notation, which all students should master as freshmen. Additionally, introductory physics should introduce students to the roles of accuracy and precision in scientific measurements, and give students a lot of practice working with significant digits.

With a background in these important skills, students will be much better prepared to tackle topics in chemistry. The reason chemistry is often perceived as difficult is that students usually have to learn chemical principles and mathematical skills simultaneously. (This is a very common situation.) When students arrive in chemistry having already mastered unit conversions, scientific notation and significant digits, a lot of the perceived difficulty of chemistry simply disappears.

In summary, placing introductory physics in 9th grade for all students provides the best access for all students to have an appropriate introduction to physics. It also introduces all students to important fundamental topics that play major roles in chemistry. Finally, studying physics in the freshman year gives all students an opportunity to master the critical skills of performing unit conversions, using scientific notation, and dealing with significant digits. With these skills in their toolbox prior to taking chemistry, the road will be

clear in chemistry to tackle the basic topics in chemistry without getting tangled up in learning the math skills at the same time.

Dual Science and Math Pathways

The majority of small private schools I have talked to place all students in Algebra in 8th grade. When a school has fewer than 10–15 students per grade in middle and high school, a one-size-fits-all math program like this is more or less an economic necessity. But it is of critical importance that placing students this way be considered a temporary measure. The fact is, on average roughly half of the students in a typical private school will be ready for Algebra in 8th grade. The other half will need an additional year of work with pre-algebra before taking Algebra in 9th grade.

There is much to say on this topic, and I have written at greater length in a previous newsletter on the reasons for stratifying math students into at least two different pathways. For that description, please see Novare Newsletter Volume 2, Issue 1, January 24, 2011 (in the newsletter archives at novarescienceandmath.com). Suffice it here to say that stratification is essential, and as soon as the number of students in each grade can support it, separate pathways should be created for grade-level students who take Algebra in 9th grade and accelerated students who take Algebra in 8th grade. (One percent or so of students will be ready for algebra in 7th grade; they can be placed with the 8th graders.)

When students are stratified into two pathways in math, the same stratification should generally apply as well to the high school science courses. Splitting students into two science pathways allows the school to provide a solid, basic sequence of courses for grade-level students while enabling accelerated students to undertake a challenging curriculum of science courses that can enable them to compete for admission into technical majors at more select colleges and universities.

We will get into some important details regarding the two course sequences

continued on page 3

Pathway	Grade-level	Accelerated
9th	Introductory Physics	Introductory Physics and Chemistry
10th	General Biology	Advanced Chemistry
11th	General Chemistry	Advanced Biology
12th	Anatomy and Physiology	Molecular Biology and/or Vector/Trig Physics

in the next two sections. To aid that discussion, the chart above shows the science course sequence I am proposing for the two pathways.

Science and Math Linkage

There is a key linkage connecting the students' math placement and the science courses they undertake each year. This key linkage relates to the math prerequisites for studying chemistry, and is one of the important factors influencing science course sequencing in both grade-level and accelerated pathways.

The prerequisite in question is the need for students to be taking (or have completed) Algebra 2 at the same time they are studying chemistry. Assuming a standard sequence in math courses (Algebra, Geometry, Algebra 2), grade-level students take Algebra 2 as juniors and accelerated students take Algebra 2 as sophomores.

A number of topics from Algebra 2 come up naturally in the study of chemistry. The definitions of pH and pOH are logarithmic expressions, and solving pH problems involves both logarithms and exponential functions. Reaction rates and chemical equilibrium involve power functions. The inclusion of these topics in chemistry requires that students take chemistry concurrently with (or after) their second year of algebra. This, in turn, places chemistry in either the sophomore or junior year, depending on math placement. The placement of chemistry into one of two different years allows for some key distinc-

tions to be put in place in the two science course sequences, distinctions that allow the school to serve each group of students appropriately. We will look at these in the next section.

The Complete Science–Math Course Sequence

Putting the science and math courses together for both pathways results in the program shown in the chart below. Two or three points should be noted right away. First, Anatomy and Physiology is a very good fit for grade-level students in 12th grade. The topics covered align closely with their natural interests, and the course is good preparation for college study. Second, the math course shown in the chart for grade-level seniors is Statistics. I recommend that this course be AP Statistics. The alignment between the AP Statistics syllabus and what would be taught in the course anyway is nearly 100%. Setting up the course with the College Board as an AP course gives the grade-level students a highlight on their transcripts. I have taught statistics at both the college and high school level to students with extremely lim-

ily challenging for them. Statistics, on the other hand, is accessible to everyone and is useful preparation for nearly every college major. Third, when student numbers permit, it is useful to stratify the junior and senior math offerings for accelerated students one step further. Students with appropriate aptitude and interest can be placed in an honors or advanced precalculus course, following that with AP Calculus. Bright students who aren't quite up for the extreme rigors of AP Calculus should take a separate precalculus class followed by a non-AP calculus course. Just as with vector/trig physics, there will be many students—even those in the accelerated pathway—who cannot handle AP Calculus. The non-AP course will be just right for them.

The considerations we have addressed so far have justified the grade-level science pathway. I haven't mentioned the grade-level sophomore biology course yet, but clearly the considerations for 9th, 11th, and 12th grade leave us with an opening in 10th grade that is appropriately filled with a general biology course.

Some other important factors are involved in the accelerated science sequence.

	Grade-level Pathway		Accelerated Pathway	
	Science	Math	Science	Math
9th	Introductory Physics	Algebra	Introductory Physics and Chemistry	Geometry
10th	General Biology	Geometry	Advanced Chemistry	Algebra 2
11th	General Chemistry	Algebra 2	Advanced Biology	Precalculus
12th	Anatomy and Physiology	Statistics	Molecular Biology and/or Vector/Trig Physics	Calculus

ited math ability and have found that when taught well virtually anyone who is not actually disabled can handle it.

I do not recommend Precalculus as a senior course for grade-level students. We have found that the material is unnecessar-

To be competitive at highly selective colleges and universities, the accelerated students will need a heavy dose of cell chemistry in their biology course. This will be much

continued on page 4

For accelerated students, “the introductory chemistry material their freshman year will allow them to move quickly into more advanced topics their sophomore year.”

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easier to accomplish if chemistry precedes biology. Happily, the math alignment in the accelerated pathway facilitates this sequencing. Now observe the line-up we have in the accelerated science course sequence. The introductory physics/chemistry course should cover the physics material by mid-to late February and then switch to chemistry. In the final three months of the year the students can get an excellent head start in chemistry, allowing us to denote the sophomore chemistry course as Advanced Chemistry. The introductory chemistry material their freshman year will allow them to move quickly into more advanced topics their sophomore year. With chemistry under their belts, the junior biology course can include a full semester of cell chemistry, along with other standard topics such as Mendelian genetics. To make room in this course for a full semester of cell chemistry, less sophisticated topics such as human organ systems should be moved down to the middle school life science course, where they are quite age appropriate. After the advanced biology as junior, students will be ready for a solid course in molecular biology their senior year, a course that is always impressive to colleges. Alternatively, students can take the vector/trig physics class. Schedules permitting, some science-minded students will want to take both.

At Regents School of Austin, where I have been teaching since 1999, we have had the most of the components of the program outlined above in place for about a decade. This program has served us very well. Students from both grade-level and accelerated pathways have returned for visits from their first or second year in college and have often commented on how well prepared they were.

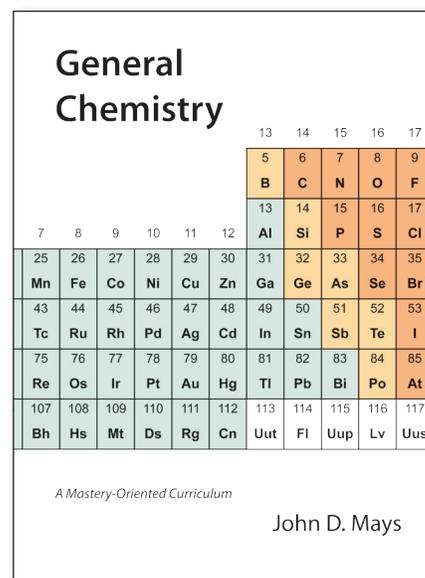
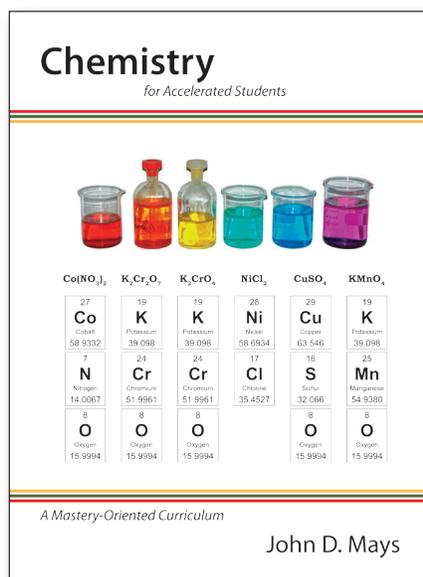
Considerations for Middle School

We will conclude with a few considerations for middle school science. The best courses to offer are Life Science, Physical Science, and Earth Science. An astronomy component in the Earth Science course is a good idea, and will make the course a lot of fun. I do not recommend omnibus courses with names like “general science.” Such courses tend to be amorphous, lacking in definition and focus. Middle school students will learn more and remember more if they are able to focus on one basic discipline for the entire year.

If your school includes 6th grade as part of the middle school, then I recommend life science, physical science, and earth science/astronomy as the sequence for 6th, 7th, and 8th grades respectively. If the middle school consists of only 7th and 8th grades, then you will need to pick two out of these three courses to offer in the middle school. One obvious way to do that is to schedule physical science and earth science/astronomy for 7th and 8th grades, and make life science the key topic for 6th grade, even though the 6th grade is part of the elementary school. Another approach is to switch the physical science and life science years and still keep one of them in 6th grade. The only sequence I would not recommend is placing physical science in 8th grade when introductory physics occurs in 9th grade. There is a lot of overlap between these courses, and it is best to spread them apart by at least one year. ▲

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