Snowmass2021 - Letter of Interest Details

Topical Group(s):

☐ (CEF1) Applications & Industry

☑ (CEF2) Career Pipeline & Development

☐ (CEF3) Diversity & Inclusion

☑ (CEF4) Physics Education

☐ (CEF5) Public Education & Outreach

☐ (CEF6) Public Policy and Government Engagement

☐ (Other) *[Please specify frontier/topical group(s)]*

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Abstract:

Considering the plethora of new physics research that would benefit from an influx of future physicists, there is a lack of true comprehension of basic physics concepts among students specifically transitioning from high school to college. Oftentimes, many undergraduates majoring in physics struggle with the fundamental “first principles” due to the algebraic approach of physics which has been a hallmark in the secondary education curriculum for far too long. A second concern with the high school physics curriculum is that students are not exposed to the area of particle physics until after matriculation to an undergraduate or graduate institution. To address both issues in the current high school physics curriculum, we present a set of restructuring goals for high schools to implement including making classical physics be calculus-based, advice to coordinate the skill set needed with the high school mathematical department, and adding a section of study on modern and particle physics.

Restructuring the High School Physics Curriculum

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Considering the plethora of new physics research that would benefit from an influx of future physicists, there is a lack of true comprehension of basic physics concepts among students specifically transitioning from high school to college. Oftentimes, many undergraduates majoring in physics struggle with the fundamental "first principles" due to the algebraic approach of physics which has been a hallmark in the secondary education curriculum for far too long. A second concern with the high school physics curriculum is that students are not exposed to the area of particle physics until after matriculation to an undergraduate or graduate institution. To address both issues in the current high school physics curriculum, we present a set of restructuring goals for high schools to implement including making classical physics be calculus-based, advice to coordinate the skill set needed with the high school mathematical department, and adding a section of study on modern and particle physics.

Introduction

Most secondary school physics curricula follow a similar template for introducing physics, usually to junior and senior students, that gives an overview of classical mechanics and electromagnetism. While it is important to learn these topics, the method in which it is often done, particularly for kinematics, uses an algebraic approach over the preferred calculus-based approach taught at the undergraduate level. This can cause students continuing on as physics majors at undergraduate institutions, to struggle with the fundamental "first principles" in their college coursework and research due to the non- intuitiveness of this method. To address the disconnect in instruction and to provide a suggestion in improving the "survey" quality of a high school physics course, we present these proposals.

1. Restructuring the Method of Instruction

Both traditional courses as well as advanced placement, AP, have promoted the algebraic approach to teaching physics [1]. However, this method of introducing fundamental physics concepts can be confusing rather than enlightening to the students who are studying physics for the first time. It can create a stumbling block to success in undergraduate level coursework and beyond. Much of what fuels this method of instruction over the calculus-based one required at the university level comes from the secondary institutions who do not require students to take a basic introductory calculus course prior to their first class in physics [2]. What is especially problematic with this instructional method, particularly for the study of classical mechanics, is that the fundamental laws of motion that have formed the bedrock of physics are taught without using the tools for complete understanding invented by Sir Isaac Newton. He created calculus before he derived his laws of motion, and not the other way around. If students are to fully appreciate the fundamental laws of nature and leave with a comprehensive understanding of physics, then they should not attempt it using only a narrow non-intuitive approach.

2. Adapting the Mathematical Preparation Needed for Success

It is understandable that many schools have not had meaningful discussions to adjust their way of teaching physics classes because it would necessitate the reorganization of mathematics departments as well. Also, those who develop and administer the secondary education curricula are usually not well versed in the specific fields of physics and advanced mathematics [3]. While teachers are certified to teach high school level physics and mathematics, several do not have formal calculus training or are uncomfortable teaching the subject. In the last few decades, there has even arisen a fear of advanced mathematics particularly among those who have not studied it beyond the high school level or have only had a cursory exposure at the undergraduate level [4]. That is something that should be addressed so that more teachers can be qualified and comfortable to teach the calculus-based physics course. It is important to point out that when students are not encouraged or exposed to higher critical thinking, as used in calculus-based physics, they become discouraged or disinterested in the subject despite having the innate curiosity for the discovery needed in the next generation of physicists. It is important that professionals in this field address this concern regarding the preparedness of future coworkers and collaborators.

Even if students or educators believe that teaching calculus across the board solely for the benefit of presenting physics in a more intuitive way at the high school level should be discouraged, we argue that high school curricula are designed to be a survey of knowledge not only in science but across all major academic disciplines. Therefore, the skills gained by learning physics in a complete, intuitive, and higher critical way will be invaluable in the preparation for all career paths even outside the sciences.

3. Incorporating Particle Physics into the Curriculum

Another concern with secondary physics education which impacts the particle physics community in particular is that students are not often exposed to the area of particle physics until well into their undergraduate studies, and sometimes not even until their graduate careers [5]. While it is important to learn the fundamental courses of classical mechanics and electromagnetism, we as a community believe that students should learn that there is more to this field than classical physics. It would also open doors for more students to become engaged, excited, and interested in becoming physicists through learning about a field that is at the forefront of modern physics research. To date, more high school seniors who plan to major in the natural sciences in college tend to favor other stem disciplines over physics [6]. This is by no means a coincidental trend. For years, high school level chemistry has been covering critical topics that form the backbone of modern physics and yet fail to mention how crucial a role physics plays in those theories. In particular, a standard secondary education chemistry course includes a large portion of physical chemistry topics on quantum physics and thermodynamics [7]. However, considering how important quantum theory is to quantum mechanics, one of the main components needed to understand particle physics, this disconnect and exclusion of an introduction to particle physics could also explain why high schoolers shy away from physics beyond the narrow approach taught in the algebraic method.

It is understandable that not everything can be covered in a single year course, or semester for those high schools utilizing a “block scheduling” method. However, this is a survey course which should introduce a variety of concepts covering the breath of physics rather than its depth. All students, regardless of whether they have the means to attend tours at national laboratories, obtain internships, and have resources outside of the classroom for additional exploration of the field, should have the opportunity to learn about topics in physics that for some seem far out of their reach. While research in many physics disciplines do rely upon the application of classical mechanics and electromagnetism, particle physics in particular could and should be a gateway for high school students to become involved in real time discovery of the world and universe in which they live. The curiosity from the inclusion of these students would be invaluable in tapping the far reaches of particle physics in the years to come.

Conclusion

Our recommendations of including a section of study within secondary physics education on particle physics, as well as restructuring the curriculum of classical physics to be calculus-based, are important changes that will lead to a more informed and inquisitive future generation of physicists who are prepared from the beginning to succeed in the work that they will do. Further analysis and suggestions on improving the high school physics curriculum will be through surveys within the Snowmass process.

References

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