Physics Competitions

Fast-Paced Events

Here are some fast-paced competitions you can participate in as a high schooler in the US:

- The $F = ma$/USAPhO exams are the premier physics competitions in the US. The $F = ma$ exam is a fast-paced multiple choice exam (75 minutes, 25 questions) focusing on tricky mechanics problems, while the USAPhO exam has longer problems which require written solutions (3 hours, 6 questions).
- The PhysicsBowl is a fast-paced multiple choice exam (45 minutes, 40 questions) at the level of AP Physics 1 and 2.
- The Science Bowl is an exciting buzzer-based team competition covering all fields of science. You need a team of four, preferably with everybody specialized in one or two subjects, and qualifying for the national competition can be very competitive if you live in a large state. To do well as the team's physics player, you need to be able to solve AP Physics 1 and 2 questions *extremely* quickly, and also have a good deal of general physics knowledge. If you have a lot of general knowledge about science, consider being the science player on a quiz bowl team.
- Check to see if your state has local science competitions. For example, in New Jersey you can participate in the New Jersey Science League.
- The Physics Unlimited Premier Competition is a fast-paced short answer exam (90 minutes, 4 questions) focusing on mechanics, which can also be taken internationally.
- It's important to remember that even if you're a hotshot at high school physics, there's a lot more to learn. For example, try playing arXiv vs. snarXiv to see if you can even tell the titles of real physics papers from randomly generated ones.

Slower-Paced Events

Next, here are some slower-paced competitions, generally open internationally. These tend to have less name recognition, but they're fun and can help build long-term problem solving skills.

- KoMaL and FYKOS are Hungarian and Czech contests for high school students which issue a problem set every month. The problems in both tend to be elegant and instructive.
- The team behind FYKOS also runs the team-based Online Physics Brawl and Fyziklani competitions, which each last a few hours and have about 50 questions. Unfortunately, you'll have to stay up late to participate if you live in the US.
- The AAPT's journal, *The Physics Teacher*, publishes a monthly problem under the column "Physics Challenge for Teachers and Students". The difficulty is usually between an $F = ma$ and a USAPhO problem.
- The Physics Unlimited Explorer Competition is a team-based, two week competition where students explore an open-ended problem and write a research paper-style report.

- The High School Mathematical Contest in Modeling and MathWorks Math Modeling Challenge are team-based, one to two day competitions where students make are faced with an open-ended real-world problem and write a report issuing policy recommendations.
- The Online Physics Olympiad is a team-based, several day competition written entirely by high schoolers. Because it's student written, the problems can be ambiguous or difficult to understand. But the contest also has fresh ideas and comes with a great deal of excitement. In 2020, it was one of the largest international physics competitions held, with about 350 teams.
- The Physics Cup is an extremely difficult competition with one question per month, with a hint released per week. The problems are very instructive, and range from applied physics to almost pure mathematics. They always are clearly posed and have unambiguous answers, but they are sometimes so hard that almost nobody can solve them even after four weeks of hints. In theory, all the problems can be solved with only high school physics. A good knowledge of Euclidean geometry tends to help.
- The Rudolf Ortvay competition is a marathon competition with about 30 questions to be solved in 10 days, requiring undergraduate physics knowledge to solve.
- The International Theoretical Physics Olympiad is a 24-hour open-book competition for teams of undergraduates. The problems tend to be deep and open-ended, and can require graduate physics knowledge or use of the research literature.

Science Fairs

A very long-term option is to consider a high school science fair, such as ISEF or Siemens, which have great name recognition. I'm not qualified to give advice on this, since I placed at the bottom of my county's science fair – my comparison of bean growing methods, with everything bought at Home Depot, was no match against the genetic engineering projects other people showed up with, using equipment from university labs.

I will only warn you that today, science fairs don't work at all like the competitions I've listed above. In these competitions, you can do well by learning physics on your own, or in any decent school, and thinking hard about it. For competitions I never needed anything but a single, $20 used textbook, but in science fairs, you need to know people. The reason is that it's impossible to come up with and carry out a novel and feasible physics research project sitting on your own at home; you need a mentor at a university. But most professors don't even have the time to work with undergraduates in research, because they lack the background of graduate students, and thus the vast majority would never work with a high schooler. So how can you get a mentor?

In practice, there are two options: either contact many professors and get extremely lucky, or have an "in". For example, you can be born to parents who themselves are professors, so they can hire you in their own labs, or send you to their friends' labs. Or you could just have very involved parents, who will dig into the system and fight for you. You can go to an elite high school which has a dedicated class that mass-produces winning science fair projects. If all else fails, you can shell out for a few hours of Zoom calls with a past science fair winner, so you can ask them how they did it. These days, they charge about $6,500 for the privilege.

Even once you have a mentor, your success in a science fair hinges on external factors. When you do high school physics competitions, or research in graduate school, success is driven by internal factors: you decide how many hours to work, which avenues look promising, and what to try next.

But a high schooler doing research almost never has the background or time to do the same. Unless you're one of the top few high schoolers in the country in terms of physics knowledge[1], success will only be possible if your mentor goes to the trouble of picking out a very concrete, well-posed subproblem for you to work on, while they handle all the details that require advanced knowledge, and guide you away from rabbit holes.[2] In my opinion, the best childhood activities are those directed as much as possible by the kids themselves. But most competitive science fair projects are necessarily crafted and driven by adults, not kids. It is not playful; it is deadly serious. In the feverish pursuit of an Ivy League college, fighting parents throw in piles of money with a desperate energy, in a scene out of Bosch.

Given all this, why do we place value on science fairs at all? Physics Olympiad problems are merely exercises designed to be solvable by high schoolers who learn the subject well. But the end goal of this learning to produce scientists who can produce completely new knowledge, years down the line. A good science fair project, however, purportedly shows that the student can produce new knowledge *today*. What could be a better signal of their potential?

That's the narrative, anyway, but I think an equally compelling argument could be made in the opposite direction. What are the traits of good researchers? There are many, but they certainly include a deep understanding of one subfield, a broad knowledge of all of physics, and the ability to make insights into difficult problems they've never seen before. These underlying skills are precisely what is trained by Olympiad problems, many of which illustrate the key insights behind real breakthroughs in physics.[3] If you really care about research, I think it's better to spend your high school years building the foundation that will someday make you a good researcher, rather than chasing the appearance of the final product.

I have nothing against science fair participants, and I'm friends with a bunch of national science fair winners, many of whom also did Olympiads. (Even my PhD advisor participated, winning the national science fair at 14 after making it to the US Physics Team at 13!) Without exception, the national winners are dedicated and brilliant. But if you want to stand a chance to qualify for the national science fairs, and you don't already know how the game is played, you're not going to find anything useful online, or even in any book. You're not going to get anywhere with $20 or a handful of beans. You need to find the right people.

[1] Having met some of these wonderful people, a good benchmark is knowing quantum field theory well by age 16.

[2] Many of my comments are specific to physics. For example, research projects in the social sciences, or in certain areas of mathematics like combinatorics, require substantially less background. Here, a high schooler really could do novel, interesting work almost entirely independently. And if you can tinker, you can make a lot of good stuff with relatively cheap electronics. On the other hand, for biology and chemistry, university mentorship and tight guidance is absolutely necessary. You need the extremely expensive equipment in university labs, and no professor is just going to let you mess with it. If you're there, they'll be giving you very explicit instructions so you don't waste their money.

[3] This is again specific to the Physics Olympiad. It's not quite as clear for the Math Olympiad, where there is a lot of emphasis on learning specialized techniques in topics like Euclidean geometry and inequalities, which rarely show up in either undergraduate math or current research. By contrast, the ideas I learned while preparing for the Physics Olympiad made college a lot easier, and I still use them in day-to-day research.