Advice After Introductory Physics

Over the years I've met a lot of high schoolers who have self-studied calculus-based physics, want to learn more, and are unsure what to do next. This document lists some resources for going further. If you want advice for how to start out learning physics or doing physics competitions, see my introductory advice file.

Deepening Core Knowledge

You're done with the introductory material after finishing a book like Halliday, Resnick, and Krane, which roughly corresponds to the MIT courses 8.01 and 8.02. See the final exams for these courses if you want to check. If you enjoyed what you learned, there are many ways to deepen your knowledge.

- To get a deeper understanding of mechanics, try the books by Kleppner and Kolenkow (1st edition) or Morin. These are used for honors introductory physics at MIT and Harvard, respectively. There's substantial overlap between the two, so just look at both and see which you like better. Morin has harder problems, but is also more "synthetic". Morin problems are about frictionless planes and massless strings, while Kleppner problems are about cars and rockets.

- For a shorter introduction to mechanics that's written in the style of more advanced physics classes, see David Tong's notes on Dynamics. All of Tong's lecture notes are also great for further study.

- Halliday, Resnick, and Krane's brief coverage of relativity probably isn't enough to confidently handle Olympiad problems on the subject. You can learn more about the subject in the last few chapters of either Kleppner and Kolenkow or Morin. I think Morin's discussion of relativistic kinematics is excellent, carefully resolving many of the confusions a beginner might have. To get a deeper understanding of relativity, see the first few chapters of *A First Course in General Relativity* by Schutz, which also contains a nice introduction to tensors.

- To get a deeper understanding of electromagnetism, the best book is *Electricity and Magnetism* (3rd edition) by Purcell and Morin. It has good problems, and just the right level for somebody coming from an introductory course. It's best known for using relativity to relate electricity and magnetism; chapter 5 is a pedagogical masterpiece.

- The thermodynamics covered in Halliday, Resnick, and Krane is more than enough for all competitions, but for a deeper understanding, I recommend *Concepts in Thermal Physics* by Blundell and Blundell. It also applies the theory to many topics in modern and applied physics.

- If you prefer lectures to books, there's an exceptional amount of good content on MIT OCW. The classic references are the 8.01 (mechanics) and 8.02 (electromagnetism) lectures by Walter Lewin, which are mathematically elementary, but which have many interesting physical examples. Also see the 8.03 (waves) lectures, and the accompanying problem solving recitations. If you've ever wanted to start learning quantum mechanics, try the 8.04 lectures by Barton Zwiebach (more clear) and Allan Adams (more energetic).

Competition Practice

There are many good sources of practice problems for competitions.

- Of course, your primary source should be recent USAPhO exams. I've recently rewritten the solutions to these exams to be clearer and more pedagogical, but make sure to give each problem your best try before peeking; there are only a few exams and it's easy to waste them. If you find any errors, email me!

- If you run out of practice USAPhOs, AAPT sells a CD-ROM of USAPhO exams going back to 1997. You can ask your physics teacher to purchase this.

- Many problem sources are listed in the Syllabus for my tutoring program, but my favorite are:
  - Jaan Kalda's study guides. These are exceptional because they pair problems with the specific ideas needed to do them, allowing for rapid progress. They leave a lot to the reader; you won't get far if you don't already know calculus-based physics well.
  - 200 Puzzling Physics Problems. This is a set of entertaining and devilishly tricky problems, mostly compiled from eastern European physics competitions. (However, I don't recommend taking this as a serious source of practice. A good number of problems rely on obscure tricks or ad hoc approximations that may not work in the real world. It's best when used as food for thought.)

More Advanced Physics

There's also a lot you can do if you want to move towards more advanced physics.

- To get a general sense of what's out there, read the introductory pages of my lecture notes, which list many of the subfields of physics and books for each one.

- If you didn't do it while learning electromagnetism, you almost certainly want to get a grasp on multivariable calculus, which is used everywhere in physics. An excellent resource is the MIT course 18.02.

- If you're following a standard college curriculum, the next thing to do is to get an understanding of waves and oscillations. This corresponds to the MIT course 8.03, with further background given in the course 18.03 on Differential Equations. The short book *Vibrations and Waves* by French is especially good.

- After that, you could jump to mid-college courses on mechanics and electromagnetism, from books such as *Classical Mechanics* by Taylor and *Introduction to Electrodynamics* by Griffiths, corresponding to the MIT courses 8.223 and 8.07. However, I think a wiser option is to use the intermediate books listed above as a stepping stone.

- After learning the material of 8.03, you could learn introductory quantum mechanics. The most common book with the lowest prereqs is *Introduction to Quantum Mechanics* by Griffiths.

- To get a deep understanding of quantum mechanics, you're going to need to learn linear algebra. The book *Introduction to Linear Algebra* by Strang, used for 18.06 at MIT, is excellent for this. You might not see why linear algebra would be useful, given how it's glossed over in high school, but if you've read this far, you'll probably be using linear algebra continually throughout your career, possibly even more than calculus, even if you don't go into physics.

- If you want an introduction to quantum mechanics that uses your linear algebra knowledge, consider Umesh Vazirani's Quantum Computation course. Quantum computation is a great way into quantum mechanics because it uses all the weirdest features of quantum mechanics in an essential way, without the distraction of solving complicated differential equations.

Many more resources are listed in the Book Recommendations thread on Physics StackExchange. If this all sounds overwhelming, don't worry! The first book you read in a subject is always the hardest. None of these books will take half the time to read that your first introductory book did.