AAPT UNITED STATES PHYSICS TEAM
AIP 2021

USA Physics Olympiad Exam Introduction

Congratulations on your qualification for the USA Physics Olympiad! Getting this far is a great achievement. By excelling on the $F = ma$ exam, you've demonstrated a keen intuition for Newtonian mechanics, and the ability to apply it under serious time pressure. We have striven to write an accessible exam, which conveys some of the excitement of real world physics problem solving. None of the questions require advanced mathematics, obscure techniques, or any results in physics beyond those covered in standard calculus-based introductory textbooks, such as *Physics*, by Halliday, Resnick, and Krane. However, most students find the exam quite challenging, for several reasons.

First, a sizable fraction of students taking the exam have only learned mechanics so far, or only algebra-based physics. If this applies to you, don't worry! Many of the members of our International Physics Olympiad teams, including several current coaches, started out this way the first time they took the exam. We hope the experience will provide a goalpost for you to broaden and deepen your physics knowledge, as it has for many others in the past.

Second, the exam format itself may be unfamiliar, because the questions are deeper than those in most introductory courses. You can prepare for this by trying past exam questions, which can be found on our website, accompanied by detailed solutions. Some more tips are provided below.

Approaching the Questions

- Don't be intimidated if a problem mentions advanced topics, such as quantum mechanics! If you're not sure how to start, read the problem statement again carefully, and think about the fundamental physical concepts that could apply.
- Most questions can be solved using careful thought, and then only simple calculus and algebra. It is rarely necessary to do lengthy calculations, such as solving a large system of equations, or finding the roots of a high-order polynomial. If you're beginning to do such a calculation, pause to consider if there's a more efficient way to find the answer.
- You may use advanced techniques, such as Lagrangians for mechanics problems, or four-vectors for relativity problems. However, they will never be necessary, and jumping to use them can obscure a simpler solution that uses only basic techniques from introductory physics.
- In general, it's best to spend some time attempting every problem, rather than spending all of your time on one problem. All problems within a part of the exam are worth the same number of points.

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Tips for Writing Solutions

- Your written solutions should be organized linearly, going from top to bottom; preferably, you should draw a box around your final result for each part. Since time is short, we recommend working on your written solutions throughout the entire time window.

- We recommend writing darkly and leaving ample margins on your solution pages, so that your entire solution will be legible when scanned. In addition, we **strongly** recommended practicing the process on the Art of Problem Solving website on a day before the exam, as you will only have 20 minutes to scan and submit your solutions on each day of the exam.

- If you realize you've made a mistake in writing part of your solution, you can gently cross out the incorrect work and continue below it. We recommend this over erasing incorrect work for several reasons: it's faster, it removes the temptation to write on top of the erased work (which can lead to illegible scans), and it preserves the work in case you realize later that it was correct after all! Even if you ultimately can't find the solution, leaving some partial but incorrect work on the page will give you an opportunity for partial credit.

- You are not required to rederive standard results, nor to explain what you are doing in complete paragraphs, nor to show every algebraic step in detail. It suffices to briefly explain the logical structure of your solution. For example, a solution to a mechanics problem might start with "By conservation of energy...", followed by some equations, then "By conservation of momentum...", and finally "Combining and solving for v_f..." and a boxed answer.

- Though it is not required, it can be very helpful to include diagrams in your solution, such as free body diagrams for mechanics problems, and PV diagrams for thermodynamics problems. A diagram can shorten your solution, since variables can be defined on it, and it often helps prevent clumsy mistakes by increasing your intuition.

- Some problems, such as 2016 A1 and 2011 A2, require you to extract a numerical answer from data. In this case, you are not required to perform a detailed statistical analysis; at most, you will have to plot a line on graph paper, and measure its slope and intercept. You do not have to use all the data provided, but you should use enough to get an accurate result.

- Some problems, such as 2015 A1, ask for an "order of magnitude estimate" or a "rough estimate." In this case, you are not expected to find an exact answer (which in some cases may be impossible), but rather to find an algebraic expression that is correct to within a factor of 10. For example, an order of magnitude estimate for the period of a pendulum is $T \sim \sqrt{L/g}$. Order of magnitude estimates can be found in many ways, such as dimensional analysis and limiting cases, or rough approximations such as replacing a varying quantity with its average. In these problems, all methods are valid as long as the answer is correct.

- Some problems, such as 2018 A2, require a solution drawn on a provided graph. In this case, you will receive full credit for each part if your graph for that part is correct, and partial credit if the graph is only partially correct. No written solution is required. However, in the event that your answer is incorrect, a written solution can increase the amount of partial credit you receive.

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