

THE EXAMS

The AP Physics B Exam is 3 hours long, divided equally between a 70-question multiple-choice section and a free-response section. The two sections are weighted equally, and a single score is reported for the B Exam.

The free-response section will usually contain 6 or 7 questions. Examples of possible formats are 2 questions of about 17 minutes each and 5 shorter questions of about 11 minutes each, or 4 questions of about 17 minutes each and 2 shorter questions of about 11 minutes each. However, future exams might include a combination of questions of other lengths.

Each Physics C Exam is 1 hour and 30 minutes long. A student may take either or both exams, and separate scores are reported for each. The time for each exam is divided equally between a 35-question multiple-choice section and a free-response section; the two sections are weighted equally in the determination of each score. The usual format for each free-response section has been 3 questions, each taking about 15 minutes. However, future exams might include a larger number of shorter questions.

The percentages of each exam devoted to each major category are specified in the preceding pages. Departures from these percentages in the free-response section in any given year are compensated for in the multiple-choice section so that the overall topic distribution for the entire exam is achieved as closely as possible, although it may not be reached exactly.

Some questions, particularly in the free-response sections, may involve topics from two or more major categories. For example, a question may utilize a setting involving principles from electricity and magnetism or atomic and nuclear physics, but parts of the question may also involve the application of principles of mechanics to this setting, either alone or in combination with the principles from electricity and magnetism or atomic and nuclear physics. Such a question would not be classified uniquely according to any particular topic but would receive partial classifications by topics in proportion to the principles needed to arrive at the answers.

On both exams the multiple-choice section emphasizes the breadth of the students' knowledge and understanding of the basic principles of physics; the free-response section emphasizes the application of these principles in greater depth in solving more extended problems. In general, questions may ask students to:

- determine directions of vectors or paths of particles;
- draw or interpret diagrams;
- interpret or express physical relationships in graphical form;
- account for observed phenomena;
- interpret experimental data, including their limitations and uncertainties;
- construct and use conceptual models and explain their limitations;
- explain steps taken to arrive at a result or to predict future physical behavior;
- manipulate equations that describe physical relationships;
- obtain reasonable estimates; or

- solve problems that require the determination of physical quantities in either numerical or symbolic form and that may require the application of single or multiple physical concepts.

Laboratory-related questions may ask students to:

- design experiments, including identifying equipment needed and describing how it is to be used, drawing diagrams or providing descriptions of experimental setups, or describing procedures to be used, including controls and measurements to be taken;
- analyze data, including displaying data in graphical or tabular form, fitting lines and curves to data points in graphs, performing calculations with data or making extrapolations and interpolations from data;
- analyze errors, including identifying sources of errors and how they propagate, estimating magnitude and direction of errors, determining significant digits or identifying ways to reduce errors; or
- communicate results, including drawing inferences and conclusions from experimental data, suggesting ways to improve experiments or proposing questions for further study.

The free-response section of each exam is printed in a separate booklet in which each part of a question is followed by a blank space for the student's solution. The same questions without the blank answer spaces are printed on green paper as an insert in the exam booklet. This green insert also contains a Table of Information and tables of commonly used equations. The Table of Information, which is also printed near the front of each multiple-choice section, includes numerical values of some physical constants and conversion factors and states some conventions used in the exams. The equation tables are described in greater detail in a later section. The green insert can be removed from the free-response answer booklet and used for reference when answering the free-response questions only.

The International System of Units (SI) is used predominantly in both exams. The use of rulers or straightedges is permitted on the free-response sections to facilitate the sketching of graphs or diagrams that might be required in these sections.

Since the complete exams are intended to provide the maximum information about differences in students' achievement in physics, students may find them more difficult than many classroom exams. The best way for teachers to familiarize their students with the level of difficulty is to give them actual released exams (both multiple-choice and free-response sections) from past administrations. Information about ordering publications is on page 81. Recent free-response sections can also be found on AP Central, along with scoring guidelines and some sample student responses.

The Free-Response Sections — Student Presentation

Students are expected to show their work in the spaces provided for the solution for each part of a free-response question. If they need more space, they should clearly indicate where the work is continued or they may lose credit for it. If students make a mistake, they may cross it out or erase it. Crossed-out work and any work shown on

the green insert will not be scored, and credit may be lost for incorrect work that is not crossed out.

In scoring the free-response sections, credit for the answers depends on the quality of the solutions and the explanations given; partial solutions may receive partial credit, so students are advised to show all their work. Correct answers without supporting work may lose credit. This is especially true when students are asked specifically to justify their answers, in which case the Exam Readers are looking for some verbal or mathematical analysis that shows how the students arrived at their answers. Also, all final numerical answers should include appropriate units.

On the AP Physics Exams the words “justify,” “explain,” “calculate,” “what is,” “determine,” “derive,” “sketch” and “plot” have precise meanings.

Students should pay careful attention to these words in order to obtain maximum credit and should avoid including irrelevant or extraneous material in their answers.

The ability to justify an answer in words shows understanding of the principles underlying physical phenomena in addition to the ability to perform the mathematical manipulations necessary to generate a correct answer. Students will be directed to justify or explain their answers on many of the questions they encounter on the AP Physics Exams. The words “justify” and “explain” indicate that the student should support the answer with prose, equations, calculations, diagrams or graphs. The prose or equations may in some cases refer to fundamental ideas or relations in physics, such as Newton’s laws, conservation of energy, Gauss’s law or Bernoulli’s equation. In other cases, the justification or explanation may take the form of analyzing the behavior of an equation for large or small values of a variable in the equation.

The words “calculate,” “what is,” “determine” and “derive” have distinct meanings on the AP Physics Exams. “Calculate” means that a student is expected to show work leading to a final answer, which may be algebraic but more often is numerical. “What is” and “determine” indicate that work need not necessarily be explicitly shown to obtain full credit. Showing work leading to answers is a good idea, as it may earn a student partial credit in the case of an incorrect answer, but this step may be skipped by the confident or harried student. “Derive” is more specific and indicates that the students need to begin their solutions with one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. The final answer, usually algebraic, is then obtained through the appropriate use of mathematics.

The words “sketch” and “plot” relate to student-produced graphs. “Sketch” means to draw a graph that illustrates key trends in a particular relationship, such as slope, curvature, intercept(s), or asymptote(s). Numerical scaling or specific data points are not required in a sketch. “Plot” means to draw the data points given in the problem on the grid provided, either using the given scale or indicating the scale and units when none are provided.

Exam questions that require the drawing of free-body or force diagrams will direct the students to “draw and label the forces (not components) that act on the [object]”, where [object] is replaced by a reference specific to the question, such as “the car when it reaches the top of the hill.” Any components that are included in the diagram will be scored in the same way as incorrect or extraneous forces. In addition, in any subsequent part asking for a solution that would typically make use of the diagram, the following will be included: “If you need to draw anything other than what you have

shown in part [x] to assist in your solution, use the space below. Do NOT add anything to the figure in part [x].” This will give students the opportunity to construct a working diagram showing any components that are appropriate to the solution of the problem. This second diagram will not be scored.

Strict rules regarding significant digits are usually not applied to the scoring of numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant digits and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Simplification of algebraic and numerical answers is encouraged, though it should always be balanced with students’ efficient use of exam time. Simplifying an answer will often reveal a characteristic of the underlying physics that may be useful in a subsequent part of the exam question. A simplified answer is the clearest way to communicate with the professors and AP teachers who score the exams. Equivalent answers are entitled to full credit, and the Exam Readers always evaluate unsimplified answers for correctness. Yet, however careful the Readers are, there is always the chance for error in their evaluations, and thus simplification may be in the students’ best interest.

Additional information about study skills and test-taking strategies can be found at AP Central.

Calculators and Equation Tables

Policies regarding the use of calculators on the exams take into account the expansion of the capabilities of scientific calculators, which now include not only programming and graphing functions but also the availability of stored equations and other data. For taking the sections of the exams in which calculators are permitted, students should be allowed to use the calculators to which they are accustomed, except as noted below.* On the other hand, they should not have access to information in their calculators that is not available to other students, if that information is needed to answer the questions.

Calculators are NOT permitted on the multiple-choice sections of the Physics B and Physics C exams. The purpose of the multiple-choice sections is to assess the breadth of students’ knowledge and understanding of the basic concepts of physics. The multiple-choice questions emphasize conceptual understanding and qualitative applications. However, many physical definitions and principles are quantitative by nature and can therefore be expressed as equations. The knowledge of these basic definitions and principles, expressed as equations, is a part of the content of physics that should be learned by physics students and will continue to be assessed in

***Exceptions to calculator use.** Calculators that are not permitted are PowerBooks and portable/handheld computers; electronic writing pads or pen-input/stylus-driven devices (e.g., Palm, PDAs, Casio ClassPad 300); pocket organizers; models with QWERTY (i.e., typewriter) keypads (e.g., TI-92 Plus, Voyage 200); models with paper tapes; models that make noise or “talk”; models that require an electrical outlet; cell phone calculators. Students may not share calculators.

the multiple-choice sections. However, any numeric calculations using these equations required in the multiple-choice sections will be kept simple. Also, in some questions, the answer choices differ by several orders of magnitude so that the questions can be answered by estimation. Students should be encouraged to develop their skills not only in estimating answers but also in recognizing answers that are physically unreasonable or unlikely.

Calculators are allowed on the free-response section of all exams. Any programmable or graphing calculator may be used except as noted on the previous page,* and students will not be required to erase their calculator memories before and after the exam. The free-response sections emphasize solving in-depth problems where knowledge of which principles to apply and how to apply them is the most important aspect of the solution to these problems.

Regardless of the type of calculator allowed, the exams are designed and scored to minimize the necessity of doing lengthy computations. When free-response problems involve calculations, most of the points awarded in the scoring of the solution are given for setting up the solution correctly rather than for actually carrying out the computation.

Tables containing commonly used physics equations are printed in the green insert provided with each exam for students to use when taking the free-response section. The equation tables may NOT be used when taking the multiple-choice section. The Table of Information and the equation tables developed for the 2012 exams are included as an insert in this book so that they can easily be removed and duplicated for use by students. This version of the tables will remain in effect until revisions are needed. When new tables are required, they will be printed and distributed with the Course Description at least a year in advance so that students can become accustomed to using them throughout the year. However, since the equations will be provided with the exams, students are NOT allowed to bring their own copies to the exam room.

One of the purposes of providing the commonly used equations is to make the free-response sections equitable for those students who do not have access to equations stored in their calculators. The availability of these equations means that in the scoring of the free-response sections little or no credit will be awarded for simply writing down correct equations or for ambiguous answers unsupported by explanations or logical development.

The equations in the tables express relationships that are encountered most frequently in AP Physics courses and exams. However, they do not include all equations that might possibly be used. For example, they do not include many equations that can be derived by combining others in the tables. Nor do they include equations that are simply special cases of any that are in the tables. Students are responsible for understanding the physical principles that underlie each equation and for knowing the conditions for which each equation is applicable.

The equations are grouped in tables according to major content category. Within each table, the symbols used for the variables in that table are defined. However, in some cases the same symbol is used to represent different quantities in different tables. It should be noted that there is no uniform convention among textbooks for the symbols used in writing equations. The equation tables follow many common conventions, but in some cases consistency was sacrificed for the sake of clarity.

In summary, the purpose of minimizing numerical calculations in both sections of the exams and providing equations with the free-response sections is to place greater emphasis on the understanding and application of fundamental physical principles and concepts. For solving problems, a sophisticated programmable or graphing calculator, or the availability of stored equations, is no substitute for a thorough grasp of the physics involved.