Section I: Multiple-Choice Section

Section I consists of 50 multiple-choice questions, presented as discrete questions or questions in sets, that represent the knowledge and science practices outlined in the learning objectives. These multiple-choice questions include two question types: single-select questions and multi-select questions having two correct answers (students need to select both correct answers to earn credit). Section I begins with 45 single-select questions, followed directly by five multi-select questions.

Section II: Free-Response Section

Section II contains three types of free-response questions and each student will have a total of 90 minutes to complete the entire section. The three free-response question types include:

- Experimental design – pertains to designing and describing an investigation, analysis of authentic lab data, and observations to identify patterns or explain phenomena
- Qualitative/quantitative translation – requires translating between quantitative and qualitative justification and reasoning
- Short-answer questions – one of which requires a paragraph-length coherent argument

Action Words

Describe / Explain - write your thoughts referencing sound physics principles

Calculate - show the starting Eq, all algebra, metric units, answer

Derive / Express - you likely aren't going to be given any #'s but must show an algebraic solution using a specific set of variables

AP Physics 1 Exam Format

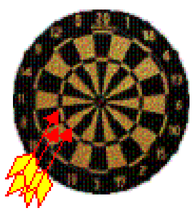
Timing	Scoring	Question Type	Number of Questions by Type	Total Number of Questions
Section I: Multiple Choice				
90 minutes	50% of exam score	Single-select (discrete questions and questions in sets with one correct answer)	45	50
		Multi-select (discrete questions with two correct answers)	5	
Section II: Free Response				
90 minutes	50% of exam score	Experimental Design	1	5
		Qualitative/Quantitative Translation	1	
		Short Answer	3	

Exam Expectations for Analysis of Uncertainty: On the AP Physics 1 exam, students will not need to calculate uncertainty but will need to demonstrate understanding of the principles of uncertainty. On the AP Physics 2 exam, students may be expected to calculate uncertainty. In general, multiple-choice questions on both exams will deal primarily with qualitative assessment of uncertainty, while free-response laboratory questions may require some quantitative understanding of uncertainty as described below.

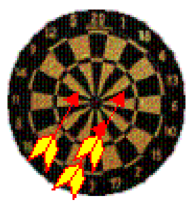
Experiment and data analysis questions on the AP Physics 1 and AP Physics 2 exams will not require students to calculate standard deviations, or carry out the propagation of error or a linear regression. Students will be expected to estimate a line of best fit to data that they plot or to a plot they are given. Students may be expected to discuss which measurement or variable in a procedure contributes most to overall uncertainty in the final result and on conclusions drawn from a given data set. They should recognize that there may be no significant difference between two reported measurements if they differ by less than the smallest difference that can be discerned on the instrument used to make the measurements. They should be able to reason in terms of percentage error and to report results of calculations to an appropriate number of significant digits. Students are also expected to be able to articulate the effects of error and error propagation on conclusions drawn from a given data set, and how results and conclusions would be affected by changing the number of measurements, measurement techniques, or the precision of measurements. Students should be able to review and critique an experimental design or procedure and decide whether the conclusions can be justified based on the procedure and the evidence presented.

Uncertainty

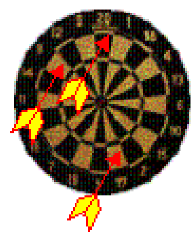
To physicists the terms "error" or "uncertainty" do not mean "mistake". Mistakes, such as incorrect calculations due to the improper use of a formula, can be and should be corrected. However, even mistake-free lab measurements have an inherent uncertainty or error. Consider the dartboards shown below, in which the 'grouping' of thrown darts is a proxy for our laboratory measurements. A 'precise' measurement means the darts are close together. An 'accurate' measurement means the darts hit close to the bullseye. Notice the combinations:



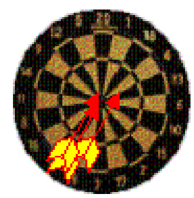
Measurements are precise,
just not very accurate



Measurements are accurate,
but not precise



Measurements neither precise nor accurate



Measurements both precise and accurate

There are several different kinds and sources of error:

Actual variations in the quantity being measured, e.g. the diameter of a cylindrically shaped object may actually be different in different places.

* The remedy for this situation is to find the average diameter by taking a number of measurements at a number of different places. Then the scatter within your measurements gives an estimate of the reliability of the average diameter you report. Note that we usually assume that our measured values lie on both sides of the 'true' value, so that averaging our measurements gets us closer to the 'truth'.
* Another approach, especially suited to the measurement of small quantities, is sometimes called 'stacking.' Measure the mass of a feather by massing a lot of feathers and dividing the total mass by their number.

Systematic errors in the measuring device used.

* Suppose your sensor reports values that are consistently shifted from the expected value; averaging a large number of readings is no help for this problem. To eliminate (or

at least reduce) such errors, we *calibrate* the measuring instrument by comparing its measurement against the value of a known standard.

*It is sometimes quite difficult to identify a systematic error. Get in the habit of checking your equipment carefully. Make a preliminary analysis of your data early in the experiment; if you gather all the data without checking for systematic error, you might have to do it all over again!

Random error: 'sometimes stuff just happens'.

*The reading of a vernier caliper may vary within the members of a lab group because each person reads it slightly differently. Or one observer's estimate of the fraction of the smallest caliper division may vary from trial to trial. The mean value computed from multiple trials averages out some of the random error; repeated measurements are required. Some people even say **"*one* measurement is *no* measurement."**

*Another subtlety is the recognition of 'outlying' or 'low probability' data points. If justifiable (and that often takes some thought), excluding 'bad data' will reduce your error.

General Procedure:

1. *Always* take your measurements in multiple trials.
2. Find the mean of your set of measurements.
3. Find the absolute value of the difference between each measurement and the mean value of the entire set.
4. Find the average of these absolute value deviations: this number is called the **"average deviation from the mean."**

Average deviation from the mean is a measure of the *precision* of the measurement: the smaller, the better.

In general, report a measurement as an average value "plus or minus" the average deviation from the mean. Another totally acceptable format is % deviation = 100 * average deviation / mean value.

For example, the chart below shows data from an experiment to measure the life of two popular brands of batteries.

(Data from Kung, Am. J. Phys., Vol. 73, No. 8, p.774).

Trial	Duracel (hours)	Energizer (hours)
1	11.4	11.6
2	12.2	7.0
3	7.8	10.6
4	5.3	11.9

5	10.3	9.0
Averages	**Duracell: 9.4 hours**	**Energizer: 10.0 hours**

The question here is: which brand of battery lasts longer? How can we tell?
Using the 'general procedure' above, calculate the deviation from the mean of each data point. Then calculate the average deviation. Thus we would report battery life for Duracell as '9.4 +/- 2.3 hours'.

Another important consideration when comparing two sets of data: the spread of the data points, sometimes called the *range of the measured values.* What does it suggest if the range of measurements for the two brands of batteries has a high degree of overlap?