AP® PHYSICS B
2006 SCORING GUIDELINES

General Notes About 2006 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. See pages 21–22 of the *AP Physics Course Description* for a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. 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 figures 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.

Question 2

15 points total | **Distribution of points**

Two general approaches were used by most of the students.

Approach A: Spread the students out every 10 meters or so. The students each start their stopwatches as the runner starts and measure the time for the runner to reach their positions.

Analysis variant 1: Make a position vs. time graph. Fit the parabolic and linear parts of the graph and establish the position and time at which the parabola makes the transition to the straight line.

Analysis variant 2: Use the position and time measurements to determine a series of average velocities ($\upsilon_{avg} = \Delta x / \Delta t$) for the intervals. Graph these velocities vs. time to obtain a horizontal line and a line with positive slope. Establish the position and time at which the sloped and horizontal lines intersect.

Analysis variant 3: Use the position and time measurements to determine a series of average accelerations $\left(\Delta x = \upsilon_0 t - at^2/2\right)$. Graph these accelerations vs. time to obtain two horizontal lines, one with a nonzero value and one at zero acceleration. Establish the position and time at which the acceleration drops to zero.

Approach B: Concentrate the students at intervals at the end of the run, in order to get a very precise value of the constant speed υ_f, or at the beginning in order to get a precise value for a_u. The total distance D is given by $D = \left(a_u t_u^2/2\right) + \upsilon_f\left(T - t_u\right)$, where T is the total measured run time. In addition, $\upsilon_f = a_u t_u$. These equations can be solved for a_u and t_u (if υ_f is measured directly) or υ_f and t_u (if a_u is measured directly). Students may have also defined and used distances, speeds, and times for the accelerated and constant-speed portions of the run in deriving these relationships.

(a) 2 points

For checking off a distance-measuring device and describing its use in part (b) — 1 point

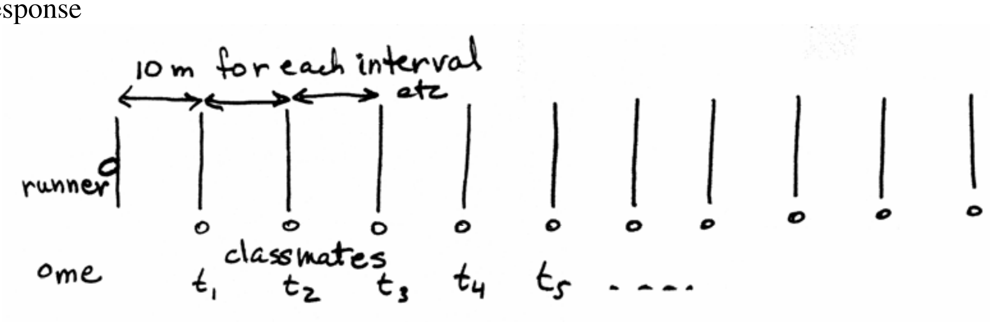
For checking off a stopwatch and describing its use in part (b) — 1 point

Question 2 (continued)

Distribution of points

(b) 6 points

Sample response



Use the tape measure and chalk to mark off the 100 meters in 10 meter lengths. Set a classmate with a stopwatch at marks as shown. Use the starter's pistol to signal the runner to run and the classmates to start their stopwatches. Each person turns off the stopwatch when the runner reaches his or her mark. You then have measurements of the time to reach each increment of 10 meters.

For taking distance measurements for 8 to 11 distinct fixed positions per run	1 point
For measuring time for the same 8 to 11 distinct fixed positions, consistent with the description of the experimental setup	1 point
For an experimental technique consistent with being able to determine the requested quantities	2 points
For a diagram of the experimental setup with clear labels and consistent with the technique described (awarded even if the technique is wrong)	1 point
For a technique that allows data for all positions to be taken in a single run	1 point

(c) 7 points

Approach A

For a clear and detailed explanation of the data analysis process	3 points
Note: This part of the solution was graded holistically and students could earn between 0 and 3 points depending on the clarity and completeness of their explanation.	
For equations or clear prose and use of the data to identify the two distinct regions of motion (constant acceleration and constant velocity)	1 point
For clearly and correctly identifying t_u	1 point
For clearly and correctly identifying a_u	1 point
For having the final answers correct and no incorrect statements or calculations among the correct ones	1 point

Question 2 (continued)

	Distribution of points
(c) (continued)	
<u>Approach B</u>	
Students needed to clearly indicate which variable was used (acceleration or final velocity) by including the following.	
For a description or diagram that clearly defines all the variables being used	1 point
For a description or diagram showing how the needed variable (acceleration or final velocity) will be determined	1 point
For a successful transformation of the above description into equation form	2 points
For correctly solving the equations obtained	1 point
For work that would determine a correct value of a_u	1 point
For work that would determine a correct value of t_u	1 point

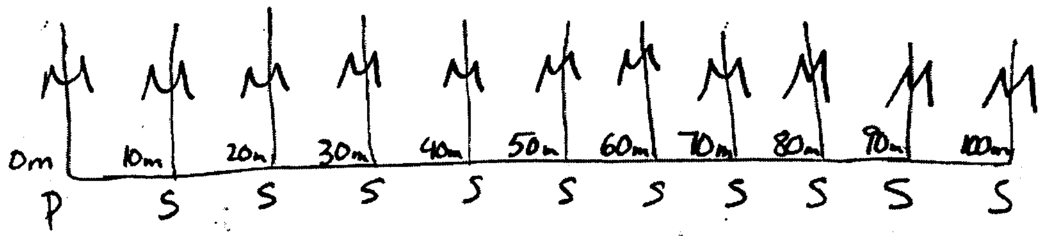
2. (15 points)

A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time t_u and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration a_u and an approximate value of t_u for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

_✓_ Stopwatches	_✓_ Tape measures	____ Rulers	_✓_ Masking tape
____ Metersticks	_✓_ Starter's pistol	____ String	____ Chalk

(b) Outline the procedure that you would use to determine a_u and t_u, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).



M= masking tape lines
S= student with stopwatch
P= student with pistol

At the sound of the pistol, the runner would begin and the students would all start their stopwatches. When the runner reached each masking tape line separated by 10m, the student at that line would stop her watch. The tape measures would have been used to create the tape markings. The data gathered would be ten different times.

(c) Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.

Each time would have the accumulated previous time subtracted from it to get 10 times of travel, each over a different 10 m. By dividing 10 m by each time, you get 10 velocities. The range of time where the velocity increases (t_u) could be observed from this data, and gotten by finding the time at which the velocity first stops increasing. To find a_u, use this formula: (V at time t_u)/t_u.

2. (15 points)

A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time t_u and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration a_u and an approximate value of t_u for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

✓ Stopwatches	✓ Tape measures	____ Rulers	____ Masking tape
✓ Metersticks	✓ Starter's pistol	____ String	✓ Chalk

(b) Outline the procedure that you would use to determine a_u and t_u, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).

① The class will measure out 100 m of the track using a tape measure and mark the beginning and end of the 100 m with Chalk.

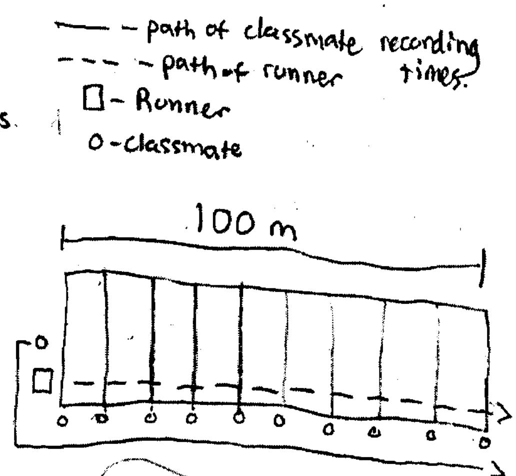
② The class will divide the 100 m into 9 equal sections each with 11.111 m using meter sticks. and mark the different sections.

③ 10 classmates will get a stopwatch and go to a line that marks a section on the hundred meters. The last Classmate will take the Starter's pistol and line up next to the runner.

④ The last classmate will fire the pistol and the runner will take off. when the pistol is fired all the classmates will start their stopwatches.

⑤ As the runner crosses each line, the classmate that corresponds to that line will stop their watch.

⑥ The classmate with the starter's pistol will then walk the 100 m and record the time of each classmate.



(c) **Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.**

① After the times are recorded, one may divide the distance (11.111 m) for each section by the time of the classmate at the end of the section minus the time of the classmate at the beginning of the section.

② Once one does this for each section, one can see the sections for which the speed of the runner is constant and remove them. The speed of the remaining sections can be averaged together to find a_u.

③ Once a_u is found one can subtract the time of the final point where the runner stops accelerating and subtract time $t=0$ to find t_u.

2. (15 points)

A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time t_u and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration a_u and an approximate value of t_u for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

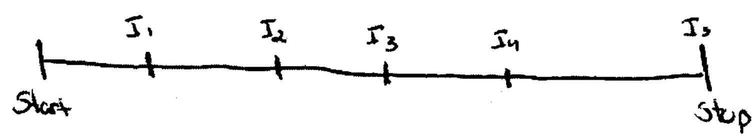
(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

✓ Stopwatches	✓ Tape measures	___ Rulers	___ Masking tape
___ Metersticks	✓ Starter's pistol	___ String	✓ Chalk

(b) Outline the procedure that you would use to determine a_u and t_u, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).

$X = \frac{V_f^2}{2a}$

$X = \frac{at^2}{2}$



1) Each student would help mark integrals separately the track into 5 even distances with chalk and measuring with tape measure.

2) each time for the integral distances would be marked separately using stop watches.

3) after the starting pistol starts the runner a total time would be calculated as well and all measurements recorded.

(c) Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.

1) Using the data gathered we can find the ~~vel~~ average velocity of the runner through segments, and at the chalk marks.

2) after finding the velocity that is constant at the end we can calculate how far the runner has run at that speed.

3) After this we can calculate the time spent accelerating then re-use this to calculate the acceleration.

$$X = \frac{vf^2}{2a}$$

$$X = \frac{at^2}{2}$$

Question 2

Overview

This was a 15-point question intended to test a student's ability to design and analyze a simple kinematics experiment. Students were to determine the magnitude and duration of the acceleration of a runner in a 100 meter dash. In part (a) students were given an equipment list and told to choose relevant equipment. In part (b) students were expected to describe a procedure and resulting data that would allow them to determine the desired quantities. In part (c) they were expected to outline the data analysis and extraction of the desired information.

Sample: B2A
Score: 15

This response uses approach A with analysis variant 2. It gives a clear and complete description of the experimental procedure and data analysis.

Sample: B2B
Score: 12

This response earned full credit for parts (a) and (b). In part (c) the student identifies two regions via the constant velocity at the end of the run and identifies t_u for 2 points. The explanation could be clearer so it only earned 2 points, and the proposed calculations are not correct so the remaining points were not credited.

Sample: B2C
Score: 6

Part (a) earned full credit, but part (b) earned only 4 points. Two points were not awarded because too few distance and time measurements are taken. In part (c) the student does not explain how to use distance and time to find velocity. The student comes close to describing intervals but switches thoughts and does not finish. There is no clear explanation here, so no points were awarded.