2017

AP CollegeBoard

AP Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

- ☑ Free Response Question 1
- ☑ Scoring Guideline
- ☑ Student Samples
- ☑ Scoring Commentary

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AP® PHYSICS
2017 SCORING GUIDELINES

General Notes About 2017 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. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. 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.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution embeds the application of that equation to the problem in other work, 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 exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam Description*.

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

6. 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.

AP® PHYSICS 1
2017 SCORING GUIDELINES

Question 1

7 points total | **Distribution of points**

(a) 2 points

Correct ranking: $(A = D = E) > (B = C)$ OR $A = D = E,\ B = C$

Note: A ranking must be given for any points to be earned for the explanation.

Note: The ranking must be correct to earn the full 2 points for the explanation.

For indicating $A = D = E$ in the ranking, with a valid explanation — 1 point

Example: "*A*, *D*, and *E* are all connected across the battery, so they must have the same ΔV as the battery."

For indicating $B = C$ in the ranking, with a valid explanation — 1 point

Example: "The same current flows through both bulbs *B* and *C*, so they have the same voltage drop across them. By Kirchhoff's voltage rule, the sum of the voltages in this circuit must add to zero, so each bulb has half the battery voltage."

Example 1: For each of bulbs *A*, *D*, and *E*, current can go around the circuit passing through only that bulb and the battery, and hence the potential drop across all three bulbs equals the voltage of the battery (because $\Delta V = 0$ for a complete loop). In circuit 2, *B* and *C* are in series so the overall potential drop (equal to the battery's voltage) is "shared" equally between the two bulbs (because they are identical) and the potential difference across each is half is the battery's voltage.

Example 2: *A*, *D*, and *E* are all connected directly across the battery terminals and therefore "get" the full battery potential difference. By contrast, the potential drop across the *BC* part of the circuit is "split" between *B* and *C*, and split equally.

Question 1 (continued)

Distribution of points

(b) 5 points

Correct answers: Circuit 3 runs out first, circuit 2 runs out last

Note: In the paragraph response, "energy dissipation" or "current" are acceptable substitutes for "power."

For indicating that all three circuits draw different amounts of power — 1 point

Note: This point may be earned by addressing only two circuits in the response.

For explaining that the battery in circuit 2 delivers the least power using correct physical reasoning by addressing potential difference OR resistance — 1 point

For explaining that the battery in circuit 3 delivers the most power using correct physical reasoning by addressing potential difference OR resistance — 1 point

For an implicit or explicit statement that greater power results in shorter battery life — 1 point

For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response — 1 point

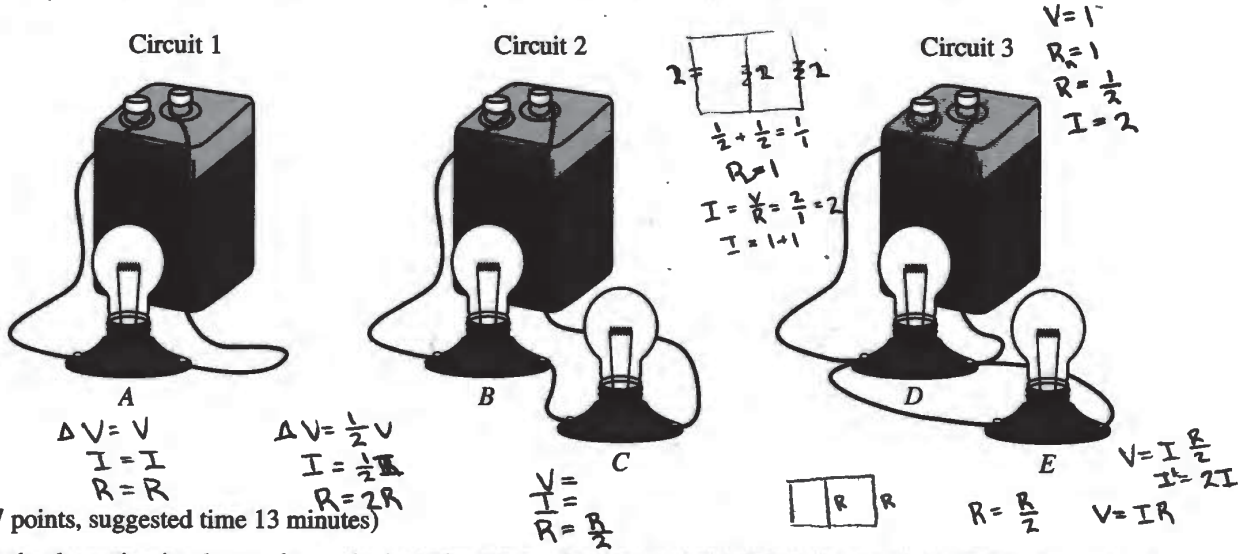
Example: The battery in circuit 3 runs out first, then the battery in circuit 1, and finally the battery in circuit 2. The power (rate of energy loss) of a battery is $P = I\Delta V$, and all three batteries have the same potential difference. So the rate of energy loss, and hence the order in which the batteries "die," is given by the ranking of the currents through the batteries. Circuit 3 has the most current because the availability of two paths (loops) makes the overall resistance of this circuit the lowest. Circuit 2 has the least current because there is only one loop, and it contains two bulbs, making the overall resistance greater than that of circuit 1.

P1 Q1 A1

PHYSICS 1
Section II
5 Questions
Time—90 minutes

	ΔV	I	R
D	2	1	2
E	2	1	2

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



2:23

1. (7 points, suggested time 13 minutes)

In the three circuits shown above, the batteries are all identical, and the lightbulbs are all identical. In circuit 1 a single lightbulb is connected to the battery. In circuits 2 and 3, two lightbulbs are connected to the battery in different ways, as shown. The lightbulbs are labeled *A*–*E*.

(a) Rank the magnitudes of the potential differences across lightbulbs *A*, *B*, *C*, *D*, and *E* from largest to smallest. If any lightbulbs have the same potential difference across them, state that explicitly.

Ranking:

ΔV: (A = D = E) > (B = C)

Briefly explain how you determined your ranking.

A, D, & E all have the potential difference ~~across~~ equal to the voltage of the battery because all have direct pathways to the battery. Bulbs B & C share access to the same battery; thus, the potential difference across them is just half that of Bulbs A, D, & E.

GO ON TO THE NEXT PAGE.

(b) The batteries all start with an identical amount of usable energy and are all connected to the lightbulbs in the circuits at the same time.

In which circuit will the battery run out of usable energy first?

___ Circuit 1 ___ Circuit 2 ✓ Circuit 3

In which circuit will the battery run out of usable energy last?

___ Circuit 1 ✓ Circuit 2 ___ Circuit 3

In a clear, coherent paragraph-length response that may also contain equations and drawings, explain your reasoning.

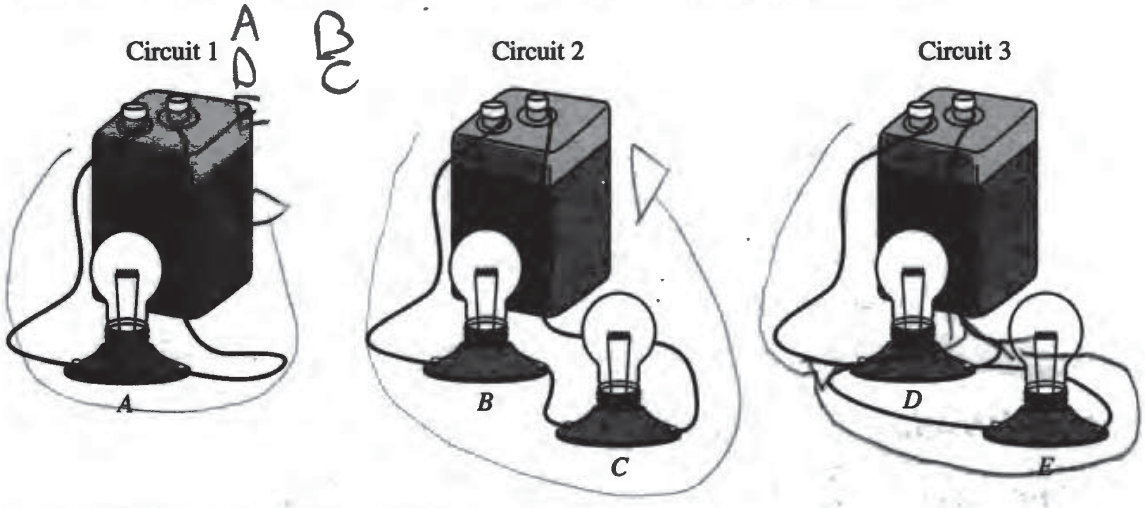
As a true parallel circuit, the battery in Circuit 3 will run out of power the soonest because it is feeding enough power to ~~two~~ power 2 bulbs at full strength. Mathematically speaking, since $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$, a parallel circuit has $1/n$ the resistance of a single bulb circuit. Therefore, the current, I, is n times that of a single bulb circuit. In this case, $n = 2$, so the battery has twice the current running through it that the battery in Circuit A would have. This increased current means that the battery runs out of energy faster. On the other hand, Circuit 2 retains energy the longest because its resistance is higher than a single bulb circuit. $R_{series} = R_1 + R_2 + \ldots$, so $R_{series} = nR$. Since $I = \frac{V}{R}$, greater resistance values for equal voltage batteries produces less current. This lower current carries energy from the battery at a slower pace; thus, the battery retains energy & keeps the lightbulbs lit longer than a single-bulb circuit.

GO ON TO THE NEXT PAGE.

P1 Q1 B1

PHYSICS 1
Section II
5 Questions
Time—90 minutes

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (7 points, suggested time 13 minutes)

In the three circuits shown above, the batteries are all identical, and the lightbulbs are all identical. In circuit 1 a single lightbulb is connected to the battery. In circuits 2 and 3, two lightbulbs are connected to the battery in different ways, as shown. The lightbulbs are labeled *A*–*E*.

(a) Rank the magnitudes of the potential differences across lightbulbs *A*, *B*, *C*, *D*, and *E* from largest to smallest. If any lightbulbs have the same potential difference across them, state that explicitly.

Ranking: A, D and E all have the same potential difference, then B and C have the same, but less than A, D, or E

Briefly explain how you determined your ranking.

Lightbulb A gets 100% of the voltage from the battery since there are no other resistors to use it. Lightbulbs D and E get the same amount since they are in parallel, which is 100% of the battery's supply. Then B and C have less voltage because they are wired in series, and have to split the voltage between themselves, but are equal to each other because they have the same resistance and current.

GO ON TO THE NEXT PAGE.

P1 Q1 B2

(b) The batteries all start with an identical amount of usable energy and are all connected to the lightbulbs in the circuits at the same time.

In which circuit will the battery run out of usable energy first?

___ Circuit 1 X Circuit 2 ___ Circuit 3

In which circuit will the battery run out of usable energy last?

___ Circuit 1 ___ Circuit 2 X Circuit 3

In a clear, coherent paragraph-length response that may also contain equations and drawings, explain your reasoning.

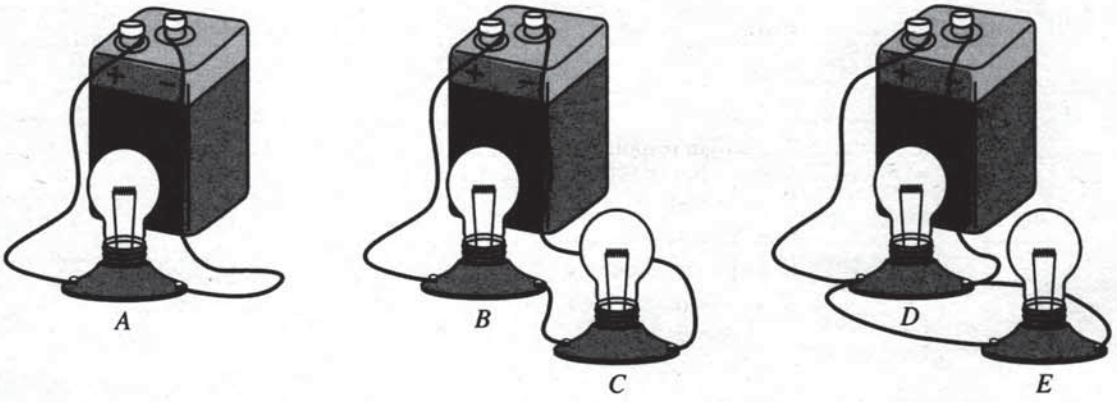
Circuit 2 is wired in series, which makes the equivalent resistance equal to the sum of the resistors, 2R. And the battery runs out quicker if the resistance in the system is higher, and since the other resistances of circuits 1 and 3 are both less than that, it makes circuit 2 run out of energy first. Circuit 3 will last the longest because it is wired in parallel and the equivalent resistance equation is $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_{total}}$. Meaning that its resistance is less than one, which is less than the other 2 systems, making it last the longest.

P1 Q1 C1

PHYSICS 1
Section II
5 Questions
Time—90 minutes

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

Circuit 1 Circuit 2 Circuit 3



1. (7 points, suggested time 13 minutes)

In the three circuits shown above, the batteries are all identical, and the lightbulbs are all identical. In circuit 1 a single lightbulb is connected to the battery. In circuits 2 and 3, two lightbulbs are connected to the battery in different ways, as shown. The lightbulbs are labeled *A*–*E*.

(a) Rank the magnitudes of the potential differences across lightbulbs *A*, *B*, *C*, *D*, and *E* from largest to smallest. If any lightbulbs have the same potential difference across them, state that explicitly.

Ranking:

A ≟ B ≟ D have the same potential difference, C, E

Briefly explain how you determined your ranking.

Lightbulbs A, B, and D are the first of the voltage drops, C has direct current going through it while E is a part of a parallel circuit.

(b) The batteries all start with an identical amount of usable energy and are all connected to the lightbulbs in the circuits at the same time.

In which circuit will the battery run out of usable energy first?

____ Circuit 1 ✓ Circuit 2 ____ Circuit 3

In which circuit will the battery run out of usable energy last?

✓ Circuit 1 ____ Circuit 2 ____ Circuit 3

In a clear, coherent paragraph-length response that may also contain equations and drawings, explain your reasoning.

Circuit 1 will last the longest simply because it uses the least amount of energy (in powering only a single light bulb). On the other hand, Circuit 2 has two lightbulbs and lacks the conserving qualities of a parallel circuit.

AP® PHYSICS 1
2017 SCORING COMMENTARY

Question 1

Overview

This question assessed learning objectives 5.B.3.1, 5.B.9.3, and 5.C.3.1.
The responses to this question were expected to demonstrate the following:

- The ability to analyze series and parallel circuits and to compare potential difference, energy, and power.
- The ability to apply Kirchhoff's loop rule to rank the potential differences across lightbulbs.
- Recognition that each circuit draws a different amount of power and the ability to correlate circuit power (or energy or current) to battery life.
- The ability to give a coherent and correct argument to support their reasoning.

Sample: P1 Q1 A
Score: 7

In part (a) both points were earned for indicating $A = D = E$ and $B = C$, with valid explanations. In part (b) full credit was earned for indicating that all three circuits draw different amounts of power, for correctly explaining why the battery in circuit 2 delivers the least power, for correctly explaining why the battery in circuit 3 delivers the most power, for implying that greater power results in a shorter battery life, and, finally, for a logical, relevant, and internally consistent argument.

Sample: P1 Q1 B
Score: 4

In part (a) both points were earned for indicating $A = D = E$ and $B = C$, with valid explanations. In part (b) 1 point was earned for implicitly indicating that all three circuits draw different amounts of power. One point was earned for a logical, relevant, and internally consistent argument.

Sample: P1 Q1 C
Score: 2

In part (b) 1 point was earned for indicating that all three circuits draw different amounts of power and 1 point was earned for implying that greater power results in a shorter battery life.