2025

AP® Physics C: Electricity and Magnetism

Sample Student Responses and Scoring Commentary

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Free-Response Question 3

- ☑ **Scoring Guidelines**
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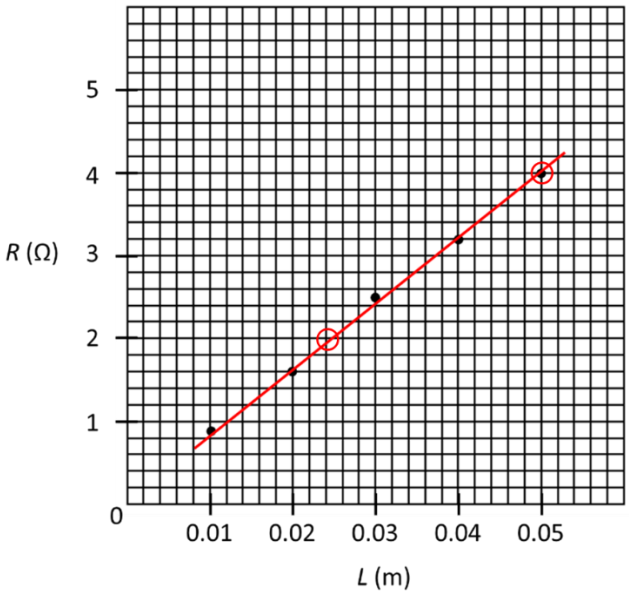
Question 3: Experimental Design and Analysis (LAB) — 10 points

A		For a procedure in which the length of and the current in the circuit element are measured, and the cross-sectional area of the circuit element is determined	**Point A1**
		For a procedure that indicates a reasonable method of reducing experimental uncertainty Examples of acceptable responses may include the following: • Making different measurements of the current in the circuit element • Varying the potential difference of the power supply	**Point A2**
		Example Response *Measure the length and diameter of the circuit element. Use the diameter to calculate the area of the circuit element. Measure the current in the circuit element. Repeat the procedure multiple times for different potential difference settings on the variable power supply.*	
B		For indicating quantities that can be graphed appropriately to determine ρ_1, consistent with the procedure from part A, such as potential difference as a function of current **Scoring Notes:** • Responses that include the reciprocals of the preceding example, in addition to other equivalent graphs, also earn this point. • This point may be earned independently of the response in part A.	**Point B1**
		For a correct analysis of the graph, consistent with the first point of part B	**Point B2**
		Example Response *Graph the potential difference across the circuit element as a function of the current in the circuit element. Use the slope of the graph, which is* $\frac{\rho_1 \ell}{\pi r^2}$*, where* ℓ *is the length of the circuit element and r is equal to the radius of the circuit element, to determine* ρ_1*.*	
C	**(i)**	For indicating appropriate quantities that could be plotted on the graph to determine ρ_2, for example R as a function of L **Scoring Note:** This point may be earned: • if the vertical and horizontal variables are reversed. • for other equivalent graphs.	**Point C1**
	(ii)	For labeling the axes (including units) with a linear scale	**Point C2**
		For correctly plotting data points consistent with **one** of the following: • The quantities indicated in part C (i) • The quantities provided in the table • The axes indicated in the first point of part C (ii)	**Point C3**
	(iii)	For drawing a line or curve that approximates the trend of the plotted data	**Point C4**

Example Response



D	For correctly relating the slope of the best-fit line to ρ_2 (e.g., $\frac{\Delta R}{\Delta L} = \text{slope} = \frac{\rho_2}{A}$)	**Point D1**
	For a value for ρ_2 that is between $3.5\times10^{-4}\ \Omega\cdot\text{m}$ and $4.5\times10^{-4}\ \Omega\cdot\text{m}$	**Point D2**

Example Response

$$\text{slope} = \frac{\Delta R}{\Delta L}$$

$$\frac{\Delta R}{\Delta L} = \frac{4.0\ \Omega - 2.0\ \Omega}{0.050\ \text{m} - 0.024\ \text{m}}$$

$$\frac{\Delta R}{\Delta L} = 77\ \frac{\Omega}{\text{m}}$$

$$R = \frac{\rho L}{A}$$

$$R = \left(\frac{\rho_2}{A}\right) L$$

$$\text{slope} = \frac{\rho_2}{A}$$

$$\rho_2 = A(\text{slope})$$

$$\rho_2 = \left(5.0\times10^{-6}\ \text{m}^2\right)\left(77\ \frac{\Omega}{\text{m}}\right)$$

$$\rho_2 \approx 3.9\times10^{-4}\ \Omega\cdot\text{m}$$

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

PART A

Set up the circuit with the variable power supply and the circuit element. Use the ruler to measure the radius of the cylindrical circuit element. Apply a power supply and using the ammeter, measure the current across the circuit. Then, using the voltmeter, measure the potential difference across the circuit element. Repeat this process with different power supplies so that the current changes and for multiple trials to reduce experimental error.
(Measure the voltage across the battery / power supply as well).

PART B

The voltage readings across the element versus the total current could be graphed to make a linear graph. Its slope could be related back to ρ_1 via slope $* \frac{\pi r^2}{l} = \rho_1$

Question 3 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

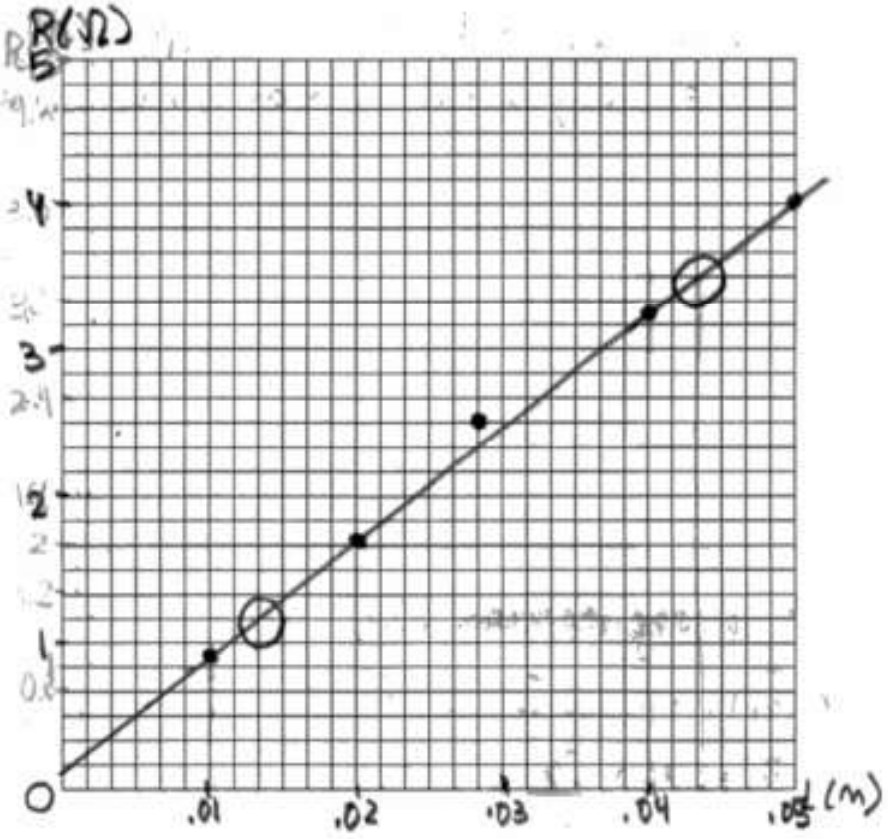
Question 3

PART C

Vertical axis: R (Ω) Horizontal axis: L (m)

L (m)	R (Ω)
.01	.90
.02	1.6
.03	2.8
.04	3.2
.05	4.0

Table 2



PART D

$\text{Slope} = \frac{\Delta R}{\Delta L} = \frac{(3.5 - 1.17)\,\Omega}{(.043 - .013)\,m} = 77.67\ \frac{\Omega}{m}$

$R = \frac{\rho \ell}{A} \qquad \rho_2 = \frac{RA}{\ell} = \text{slope} \times A = (77.67)(5.0 \times 10^{-6})\,m^2$

$\rho_2 = (3.88 \times 10^{-4})\ \Omega m$

Go to Question 4 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

PART A

To find P_1 the students could measure the current flowing through the circuit and find the change in ~~potential energy~~ electric potential over time (ΔV).

PART B

Since $R = \frac{\Delta V}{I}$, the can make ΔV the y-axis & I the x-axis, to find P_1.

Question 3 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

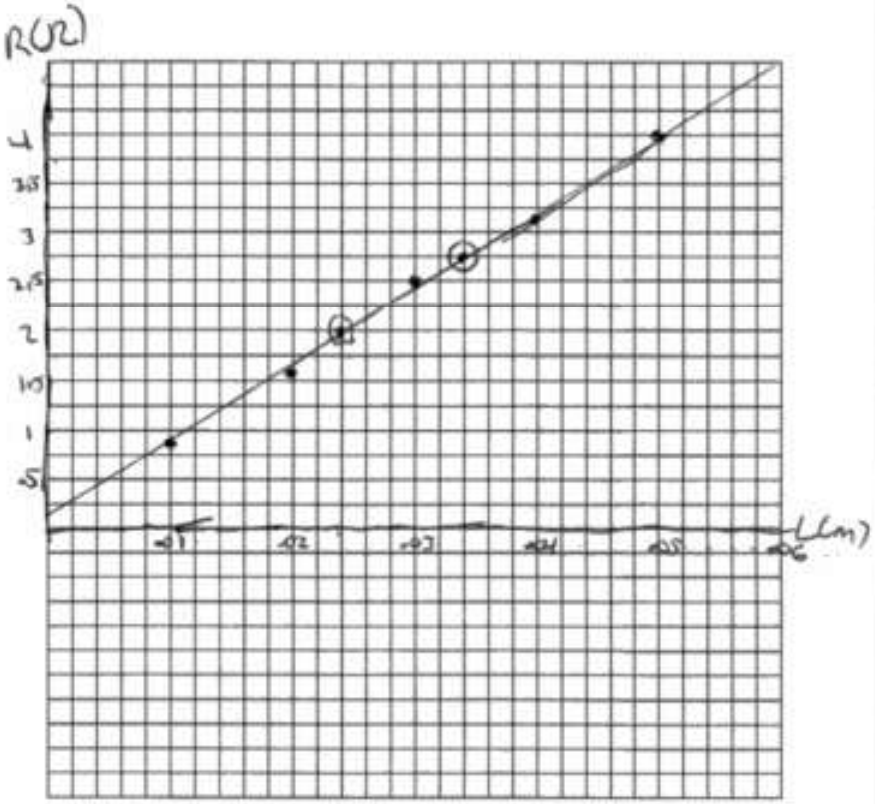
Question 3

PART C

Vertical axis: R(Ω) Horizontal axis: L (m)

L (m)	R (Ω)
.010	1.90
.020	1.60
.030	2.5
.040	3.2
.050	4.0

Table 2



PART D

$$\frac{2.75 - 2}{.034 - .024} = 75$$

$$\ln(75) = 4.317$$

Go to Question 4 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

PART A To determine ρ from a graph, the students should use the ruler to measure the length of the circuit, the voltmeter to measure the voltage of the circuit, and the ammeter to measure the ~~Resistivity~~ ~~for each trial, the~~ The students should record these values for each trial. For each trial, change the distance L (length) and record how the Resistivity and voltage changed in response (record the ~~value~~ measurement). Use the ruler to measure the area. Can do so multiple times to reduce error.

PART B To graph the collected data in part A, students should plot the resistivity (R) against the length ($\frac{1}{L}$), using this graph and the equation $R = \frac{\rho L}{A}$, students should plug in values into $\rho = \frac{AR}{L}$ to solve for and determine ρ.

Question 3 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

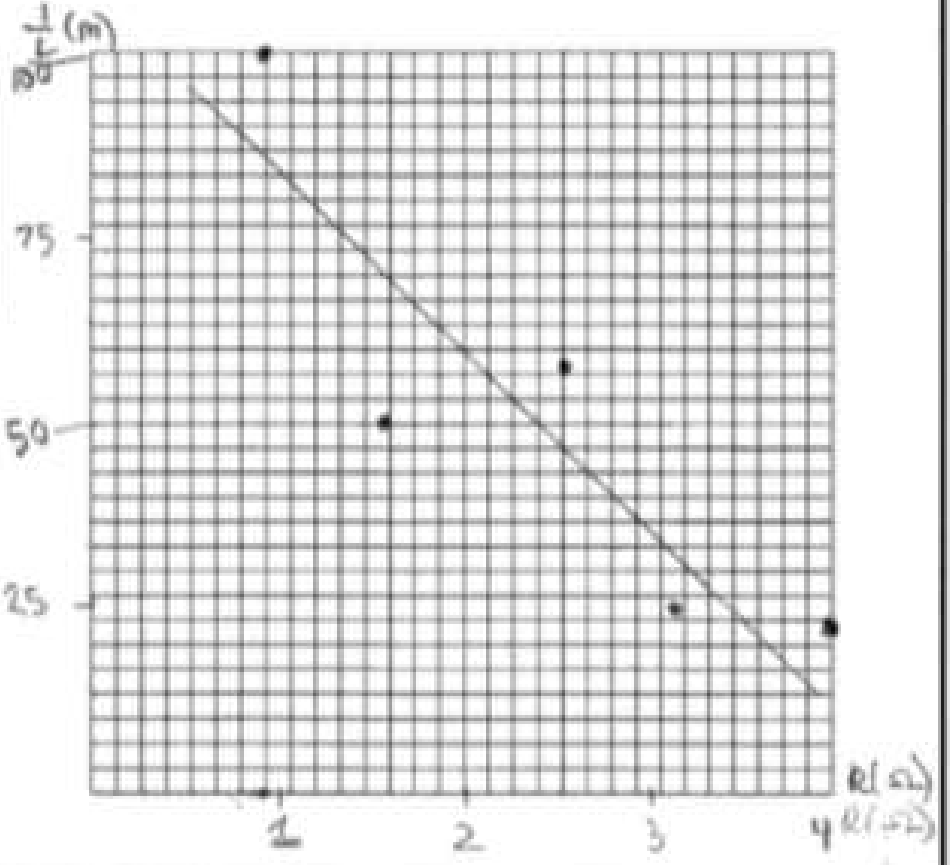
Question 3

PART C

Vertical axis: 1/L (m) Horizontal axis: R (Ω)

1/L (m)	R (Ω)
100	0.90
50	1.6
33.33	2.5
25	3.7
20	4.4

Table 2



PART D

$R = \frac{\rho L}{A}$ $\rho_1 = \frac{AR}{L} = \frac{(5 \times 10^{-4})(4)}{(20)}$

$\rho_1 = 1 \times 10^{-6}$

Go to Question 4 in Bluebook when you're done with this question.

Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

NEW for 2025: The question overviews can be found in the *Chief Reader Report on Student Responses* on AP Central.

Sample: 3A
Score: 9

Part A earned one out of two points. The first point (A1) was not earned because the response doesn't indicate measuring the length of the circuit element. The second point (A2) was earned for indicating multiple measurements were made to reduce uncertainty.

Part B earned both points. The first point (B1) was earned for stating that voltage and current should be graphed to find the resistivity value. The second point (B2) was earned for indicating that the slope of the line is correctly related to the resistivity.

Part C (i) earned the point. The point (C1) was earned for stating that resistance and length should be graphed to find the resistivity value. Part C (ii) earned both points. The first point (C2) was earned for showing a correct linear scale with appropriate labels and units. The second point (C3) was earned for correctly plotting data points on the graph from a data table. Part C (iii) earned the point. The point (C4) was earned for drawing an appropriate trend line through the data points.

Part D earned both points. The first point (D1) was earned for correctly relating the slope of the best-fit line to the resistivity. The second point (D2) was earned for indicating a numerical value of the resistivity within the acceptable range.

Sample: 3B
Score: 6

Part A earned one out of two points. The first point (A1) was not earned because the response only measures current, not length, and does not determine cross-sectional area. The second point (A2) was earned for indicating multiple measurements were made to reduce uncertainty ("over time").

Part B earned one out of two points. The first point (B1) was earned for stating that voltage and current should be graphed to find the resistivity value. The second point (B2) was not earned because the response does not correctly analyze the graph in point B1. The resistivity is not related to the slope of the plotted data.

Part C (i) earned the point. The point (C1) was earned for stating that resistance and length should be graphed to find the resistivity value. Part C (ii) earned both points. The first point (C2) was earned for showing a correct linear scale with appropriate labels and units. The second point (C3) was earned for correctly plotting data points on the graph from a data table. Part C (iii) earned the point. The point (C4) was earned for drawing an appropriate trend line through the data points.

Part D did not earn either point. The first point (D1) was not earned because the response does not correctly relate the slope of the best-fit line to the resistivity. The second point (D2) was not earned because the response does not indicate a numerical value of the resistivity within the acceptable range.

Question 3 (continued)

Sample: 3C
Score: 3

Part A earned one out of two points. The first point (A1) was not earned because the response does not measure current. The response also does not indicate a correct determination of area. The second point (A2) was earned for indicating multiple measurements were made to reduce uncertainty.

Part B did not earn either point. The first point (B1) was not earned because the response does not state that voltage and current should be graphed to find the resistivity value. The second point (B2) was not earned because the response does not indicate that the resistivity is related to the slope of the graph.

Part C (i) did not earn the point. The point (C1) was not earned because the response does not indicate appropriate quantities that could be plotted on the graph to determine the resistivity. Part C (ii) earned one out of two points. The first point (C2) was not earned because the response does not indicate correct units for the quantity on the vertical axis. The second point (C3) was earned for correctly plotting data points on the graph from a data table. Part C (iii) earned the point. The point (C4) was earned for drawing an appropriate trend line through the data points.

Part D did not earn either point. The first point (D1) was not earned because the response does not correctly relate the slope of the best-fit line to the resistivity. The second point (D2) was not earned because the response does not indicate a numerical value of the resistivity within the acceptable range.