2025

AP® Physics 2: Algebra-Based

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 that includes **both** of the following measurements: • The dimensions of the capacitor • A current	**Point A1**
	For a procedure that indicates an appropriate method of reducing experimental uncertainty (e.g., Repeat the procedure multiple times.)	**Point A2**
	Example Responses *Measure the length of one side of a capacitor plate. Measure the separation distance between the plates. Construct a circuit that includes the battery and the resistor. Measure the current in the resistor. Repeat measurements of current in the resistor for the described closed circuit.* *Measure the length of one side of a capacitor plate. Measure the separation distance between the plates. Construct a circuit that includes the battery, resistor, and capacitor. Measure the initial current in the resistor after the closed circuit is constructed. Disconnect the capacitor from the circuit, discharge the capacitor, and repeat the procedure.*	
B	For indicating that $\tau = R_{eq}C_{eq}$ can be used to calculate τ	**Point B1**
	For **both** of the following: • A correct relationship between resistance, the emf of the battery, and current (e.g., $R_{eq} = \frac{\mathcal{E}}{I}$) • A correct relationship between capacitance, the area of a capacitor plate, and the distance between the capacitor plates (e.g., $C_{eq} = \varepsilon_0 \frac{A}{d}$)	**Point B2**
	Example Responses $\tau = R_{eq}C_{eq}$ *can be used to determine* τ. R_{eq} *can be determined by using* $R_{eq} = \frac{\mathcal{E}}{I}$, *where I is the current in the resistor when the resistor is connected to the battery.* C_{eq} *can be determined by using* $C_{eq} = \varepsilon_0 \frac{A}{d}$, *where d is the distance between the capacitor plates and A is the square of the length of a capacitor plate.* $\tau = R_{eq}C_{eq}$ *can be used to determine* τ. R_{eq} *can be determined by using* $R_{eq} = \frac{\mathcal{E}}{I}$, *where I is the initial current in the resistor when the resistor is connected in series with the battery and the capacitor.* C_{eq} *can be determined by using* $C_{eq} = \varepsilon_0 \frac{A}{d}$, *where d is the distance between the capacitor plates and A is the square of the length of a capacitor plate.*	

C	**(i)**	For indicating appropriate quantities that can be plotted to produce a linear graph to determine *C* **Scoring Note:** Any response that correctly identifies the functional dependence between varied quantities earns this point, regardless of any coefficients that contain numbers or physical/fundamental constants, or which axis is chosen to graph each of those quantities.	**Point C1**

Example Responses

q *as a function of* $\lvert\Delta V\rvert$

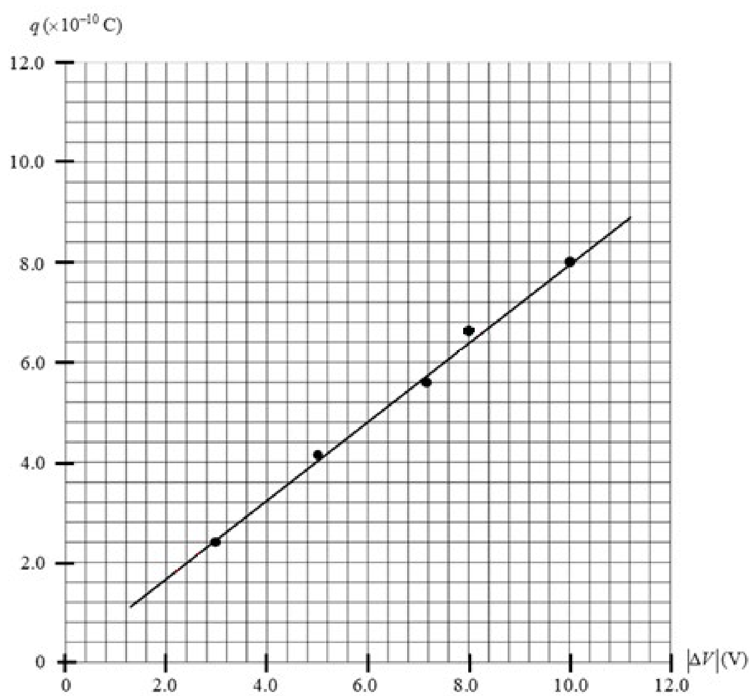
$\lvert\Delta V\rvert$ *as a function of* q

$\dfrac{1}{q}$ *as a function of* $\dfrac{1}{\lvert\Delta V\rvert}$

$\dfrac{1}{\lvert\Delta V\rvert}$ *as a function of* $\dfrac{1}{q}$

(ii)	For labeling the axes (including units) with a linear scale	**Point C2**
	For correctly plotting the 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 point C2	**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 straight line graph to $q = C|\Delta V|$ or a correct equation that is consistent with an appropriate graph that can be used to determine C (e.g., $\frac{\Delta q}{\Delta|\Delta V|} = \text{slope} = C$) **Point D1**

Example Responses

The slope of q *as a function of* $|\Delta V|$ *is* C.

The slope of $|\Delta V|$ *as a function of* q *is* $\frac{1}{C}$.

The slope of $\frac{1}{q}$ *as a function of* $\frac{1}{|\Delta V|}$ *is* $\frac{1}{C}$.

The slope of $\frac{1}{|\Delta V|}$ *as a function of* $\frac{1}{q}$ *is* C.

For a value for C that is approximately equal to 8×10^{-11} F, within the range $7 \times 10^{-11}\text{ F} \le C \le 9 \times 10^{-11}\text{ F}$ **Point D2**

Scoring Notes:

- If the slope of the plotted data points is equal to the quantity that is supposed to be determined, a correct, isolated final value earns points D1 and D2.
- If the slope of the plotted data points is not equal to the quantity that is supposed to be determined, a correct, isolated final value earns point D2 only.

Example Response

$$\text{slope} = \frac{\Delta q}{\Delta|\Delta V|}$$

$$\frac{\Delta q}{\Delta|\Delta V|} = \frac{(6.4 \times 10^{-10}\text{ C}) - (2.0 \times 10^{-10}\text{ C})}{8.0\text{ V} - 2.4\text{V}}$$

$$\frac{\Delta q}{\Delta|\Delta V|} = 7.9 \times 10^{-11}\ \frac{\text{C}}{\text{V}}$$

$$C = \frac{Q}{\Delta V}$$

$$q = C|\Delta V|$$

$$\text{slope} = C$$

$$C \approx 8 \times 10^{-11}\text{ F}$$

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

$\tau = R_{eq}C_{eq}$, so we must first find R + C. To find R_{eq}, the student should create a circuit with the battery, switch, the resistor, and the ammeter in series, Do multiple trials and record the average current. To find Capacitance, the student should measure the length of side of the capacitor, then square it to get the Area A, doing multiple readings and average to increase accuracy. Then measure the distance between the plates with the ruler, using multiple accurate readings and averaging them to get the distance d.

PART B

Take the current from resistor measurement, divide battery voltage by this, as $V=IR$ so $\frac{V}{I}=R$. Now resistance is known. Use the area measurement A of the capacitor and distance between plates d, then calculate $\kappa\varepsilon_0\frac{A}{d}$, where $\kappa=1$ as dielectric of air is 1 and $\varepsilon_0 = 8.85\times10^{-12}\frac{C^2}{Nm^2}$. This yields capacitance as $C=\kappa\varepsilon_0\frac{A}{d}$. Since the resistor + capacitor are in series, $\tau = R_{eq}C_{eq}$. So by multiplying C and R which we just calculated, we are left with τ, the time constant

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

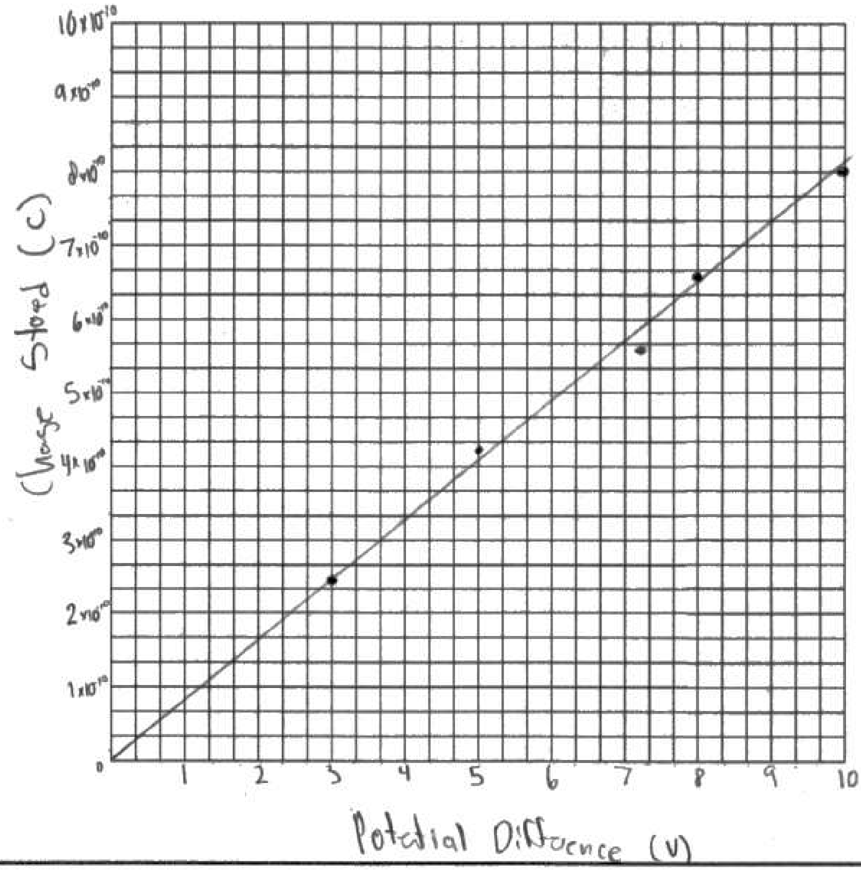
PART C

Vertical axis: Charge (q) Horizontal axis: Potential Difference (|ΔV|)

$\lvert\Delta V\rvert$	Q
3.0 V	2.4×10^{-10} C
5.0 V	4.2×10^{-10} C
7.2 V	5.6×10^{-10} C
8.0 V	6.6×10^{-10} C
10.0 V	8.0×10^{-10} C

Table 2

$C = \frac{Q}{\Delta V}$



PART D $(3.66, 3\times10^{-10})$ $(9, 7.33\times10^{-10})$

$$C = \frac{Q}{\Delta V} = \frac{\Delta y}{\Delta x} = \frac{(7.33\times10^{-10} - 3\times10^{-10})\ \text{C}}{(9-3.66)\ \text{V}} = \boxed{8.11\times10^{-11}\ \frac{\text{C}}{\text{V}}}$$

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

$\tau = R_{eq} C_{eq}$

- Time constant 'τ' = $R_{eq} \cdot C_{eq}$

1 - Create a circuit with the battery, open switch, & resistor all in series

2 - Close switch & immediately measure current (I) w/ ammeter

3 - Use known values V & I in equation $V = IR$ to find resistance

4. Use ruler to measure a side (s) of the capacitor, then use equation $A = s^2$ to find area

5. Use ruler to measure plate separation in capacitor

PART B

$\tau = R \cdot C$

- Use known emf of battery 'V' & measured current 'I' in the equation $V = IR$, and solve for R (Resistance)

- Find Capacitance (C) ~~with~~ with equation $C = K\varepsilon_0 \frac{A}{d}$, where K & ε_0 are known constants and A (Area) & d (distance) are measured values

- Multiply together to find τ

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

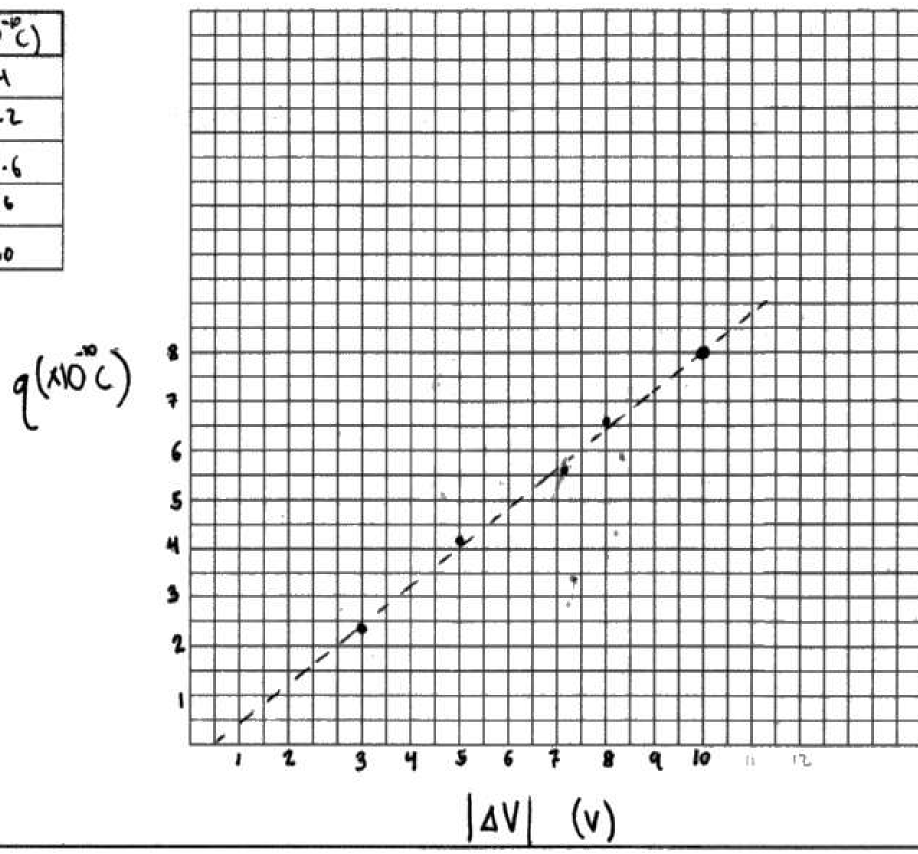
Vertical axis: $q (\times 10^{-10} C)$ Horizontal axis: $|\Delta V| (V)$

$\Delta V (V)$	$q (\times 10^{-10} C)$
3	2.4
5	4.2
7.2	5.6
8	6.6
10	8.0

Table 2

$C = \frac{Q}{\Delta V}$ y=mx+b

Q CΔV



PART D

$$\frac{\Delta y}{\Delta x} \rightarrow \frac{(8-2.4)}{(10-3)} = \frac{5.6}{7} \approx \boxed{C = 0.8 \, C/V}$$

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 The Procedure that ~~can~~ should be used to Determine the expected time constant "(τ)" by the Student is this.

Step 1 - Student Shoud gather these materials Ammeter, Switch, Battery, cappacitor, ~~#~~ ressistor, wires.

Step 2 - Student Shoud Set up the circuit in series with all the equipment gathered.

Step 3 - Student is going to record this experiment at least 10 times to ensure the most accurate data Possible, Student is going to use said data by using the ammeters for both reading and measuring when the cappacitor gets to full capacitance, and for the ressistors too, then Student can use "τ = ReqCeq to find the time constant.

PART B The collected data of the Ressistors and cappacitors can be used in this equation "(τ)" $\tau = R_{eq} \cdot C_{eq}$ to find the time constant (τ)

Because we found cappacitance with the ammeters and ressistance with them as well we have the required numbers for the time constant.

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.

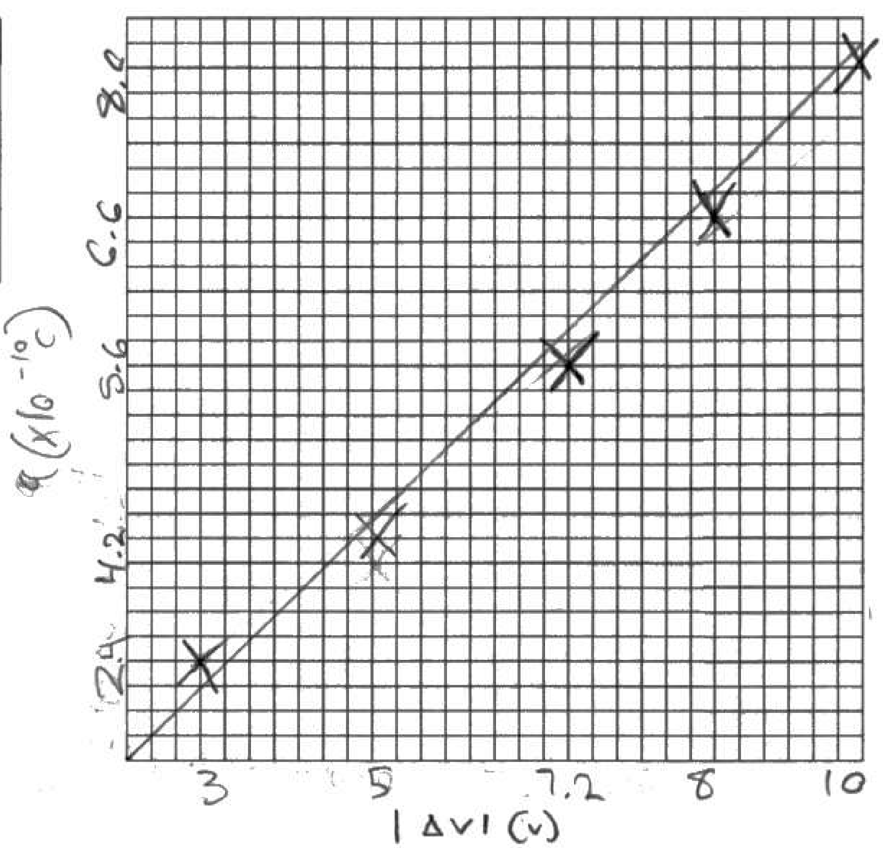
Question 3

PART C

Vertical axis: Change in |voltage| Horizontal axis: Change in charge ($\times 10^{-10}$ C)

$\lvert\Delta V\rvert$ (V)	q ($\times 10^{-10}$ C)
3.0	2.4
5.0	4.2
7.2	5.6
8.0	6.6
10.0	8.0

Table 2



PART D

80

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

Q5520/17

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: 10

Part A earned both points. The first point (A1) was earned because the response indicates a procedure in which the dimensions of the capacitor are measured, and the current is measured. The second point (A2) was earned because the response indicates a procedure that includes an appropriate method of reducing experimental uncertainty by repeating the procedure multiple times.

Part B earned both points. The first point (B1) was earned because the response indicates calculating the expected time constant by multiplying the resistance of the resistor by the capacitance of the capacitor. The second point (B2) was earned because the response correctly relates both the resistance to the battery emf and measured current as well as the capacitance to the area of and distance between the capacitor plates.

Part C (i) earned the point. The point (C1) was earned because the response indicates appropriate quantities that can be plotted to produce a linear graph to determine capacitance. Part C (ii) earned both points. The first point (C2) was earned because the response labels the axes (including units) with a linear scale. The second point (C3) was earned because the response plots the data points correctly. Part C (iii) earned the point. The point (C4) was earned because the response draws an appropriate best-fit line that approximates the trend of the data.

Part D earned both points. The first point (D1) was earned because the response relates the slope of the straight-line graph to the capacitance of the capacitor. The second point (D2) was earned because the response calculates a value for the capacitance that is within the accepted range of values.

Question 3 (continued)

Sample: 3B
Score: 8

Part A earned one out of two points. The first point (A1) was earned because the response indicates a procedure in which the dimensions of the capacitor are measured, and the current is measured. The second point (A2) was not earned because the response does not indicate a procedure that includes an appropriate method of reducing experimental uncertainty by repeating the procedure multiple times.

Part B earned both points. The first point (B1) was earned because the response indicates calculating the expected time constant by multiplying the resistance of the resistor by the capacitance of the capacitor. The second point (B2) was earned because the response correctly relates both the resistance to the battery emf and measured current as well as the capacitance to the area of and distance between the capacitor plates.

Part C (i) earned the point. The point (C1) was earned because the response indicates appropriate quantities that can be plotted to produce a linear graph to determine capacitance. Part C (ii) earned both points. The first point (C2) was earned because the response labels the axes (including units) with a linear scale. The second point (C3) was earned because the response plots the data points correctly. Part C (iii) earned the point. The point (C4) was earned because the response draws an appropriate best-fit line that approximates the trend of the data.

Part D earned one out of two points. The first point (D1) was earned because the response relates the slope of the straight-line graph to the capacitance of the capacitor. The second point (D2) was not earned because the response does not calculate a value for the capacitance that is within the accepted range.

Sample: 3C
Score: 5

Part A earned one out of two points. The first point (A1) was not earned because the response indicates a procedure in which current is measured, but the response does not indicate a procedure in which the dimensions of the capacitor are measured. The second point (A2) was earned because the response indicates a procedure that includes an appropriate method of reducing experimental uncertainty by repeating the procedure multiple times.

Part B earned one out of two points. The first point (B1) was earned because the response indicates calculating the expected time constant by multiplying the resistance of the resistor by the capacitance of the capacitor. The second point (B2) was not earned because the response does not relate the resistance to the battery emf and measured current or the capacitance to the area of and distance between the capacitor plates.

Part C (i) earned the point. The point (C1) was earned because the response indicates appropriate quantities that can be plotted to produce a linear graph to determine capacitance. Part C (ii) earned one out of two points. The first point (C2) was not earned because the response labels the axes (including units), but the response does not use a linear scale. The second point (C3) was earned because the response plots the data points correctly according to the scale used. Part C (iii) earned the point. The point (C4) was earned because the response draws an appropriate best-fit line that approximates the trend of the data.

Part D did not earn either point. The first point (D1) was not earned because the response does not relate the slope of the straight-line graph to the capacitance of the capacitor. The second point (D2) was not earned because the response does not calculate a value for the capacitance that is within the accepted range.