AP® PHYSICS
2012 SCORING GUIDELINES

General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if the use of an 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 sheets. 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 Course Description*.

4. 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.

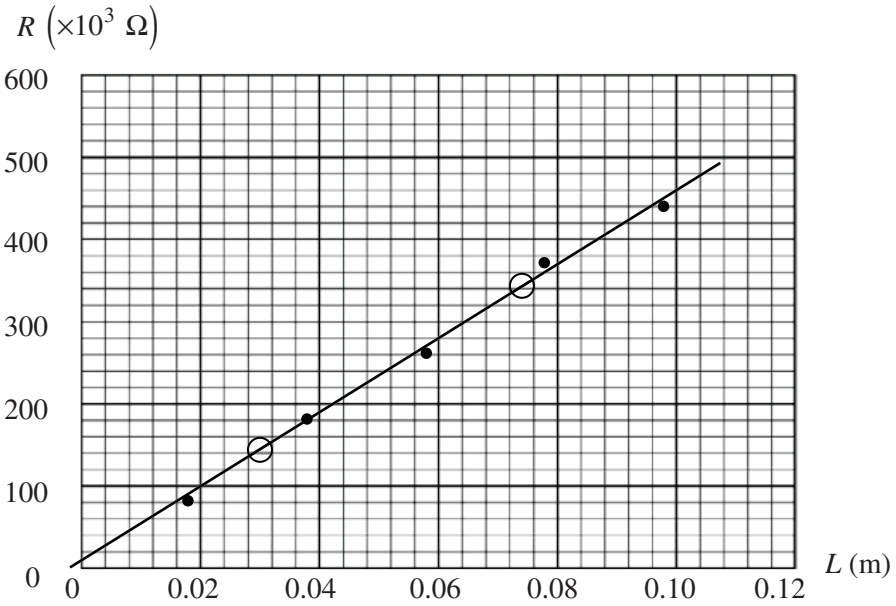
5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer owing to differences 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

AP® PHYSICS C: ELECTRICITY AND MAGNETISM
2012 SCORING GUIDELINES

Question 2

15 points total **Distribution of points**

(a) 4 points



For a correct label on each axis (one including resistance, one including length), that leads to a linear graph — 1 point

For two linear scales, one for each axis, corresponding to the labels and occupying at least three-quarters of each axis — 1 point

For reasonably correctly plotted points according to the scale — 1 point

For a reasonable best-fit straight line — 1 point

Note: Circles on the graph are to indicate points chosen to calculate slope in part (b). They are not necessary to receive credit.

Question 2 (continued)

Distribution of points

(b) 3 points

For correctly using the equation $R = \rho L/A$ to solve for the resistivity — 1 point

$\rho = (R/L)A$

For calculating the slope m from two points that lie on the indicated best-fit line — 1 point

Example (using the two points indicated on the graph)

$m = \Delta R/\Delta L = \left(340 \times 10^3\ \Omega - 140 \times 10^3\ \Omega\right)\Big/(0.076\ \text{m} - 0.032\ \text{m})$

$m = 4.55 \times 10^6\ \ \Omega/\text{m}$

Note: The slope point can also be earned for indicating that a linear regression function on a calculator was used (exact answer required): $m = 4.5 \times 10^6\ \ \Omega/\text{m}$ (to two significant figures).

$\rho = mA = mtw$

$\rho = \left(4.5 \times 10^6\ \ \Omega/\text{m}\right)\left(1.0 \times 10^{-4}\ \text{m}\right)(0.02\ \text{m})$

For a correct answer, with supporting work — 1 point

$\rho = 9.0\ \Omega\bullet\text{m}$ ($\pm 0.2\ \Omega\bullet\text{m}$ is acceptable)

(c) 3 points

For correctly stating the RC circuit time constant equation — 1 point

$\tau = RC$

For the correct value of the equivalent resistance — 1 point

$$\frac{1}{R_P} = \frac{1}{R4} + \frac{1}{R5} = \frac{1}{(370\ \text{k}\Omega)} + \frac{1}{(440\ \text{k}\Omega)}$$

$R_P = 201\ \text{k}\Omega$

For the correct value of the time constant (units not evaluated here) — 1 point

$\tau = R_P C = (201\ \text{k}\Omega)(10\ \mu\text{F})$

$\tau = 2.01\ \text{s}$

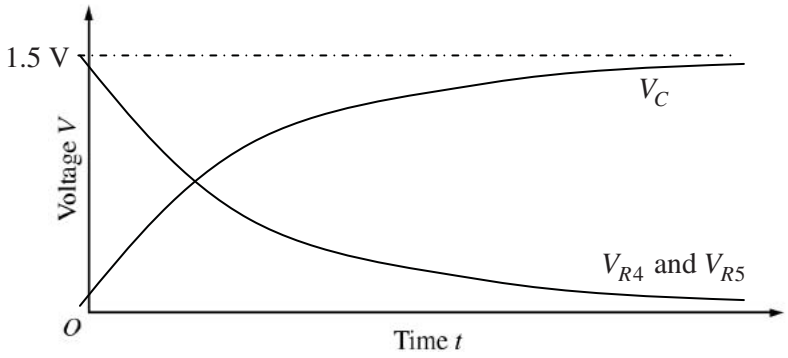
Units 1 point

For correct units for the answers in both parts (b) and (c) — 1 point

Question 2 (continued)

Distribution of points

(d) 4 points

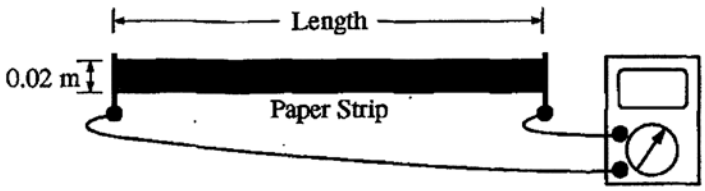


For correctly indicating the battery voltage as an asymptote for the V_C curve (or in the absence of a correct V_C curve, as the maximum of the resistor curves) — 1 point

For a capacitor voltage curve starting at the origin, increasing, concave down, and appropriately labeled — 1 point

For a resistor voltage curve starting at the intersection of the asymptotic voltage with the voltage axis, decreasing and concave up (asymptotic with the time axis), and appropriately labeled — 1 point

For any indication that $V_{R4} = V_{R5}$ — 1 point

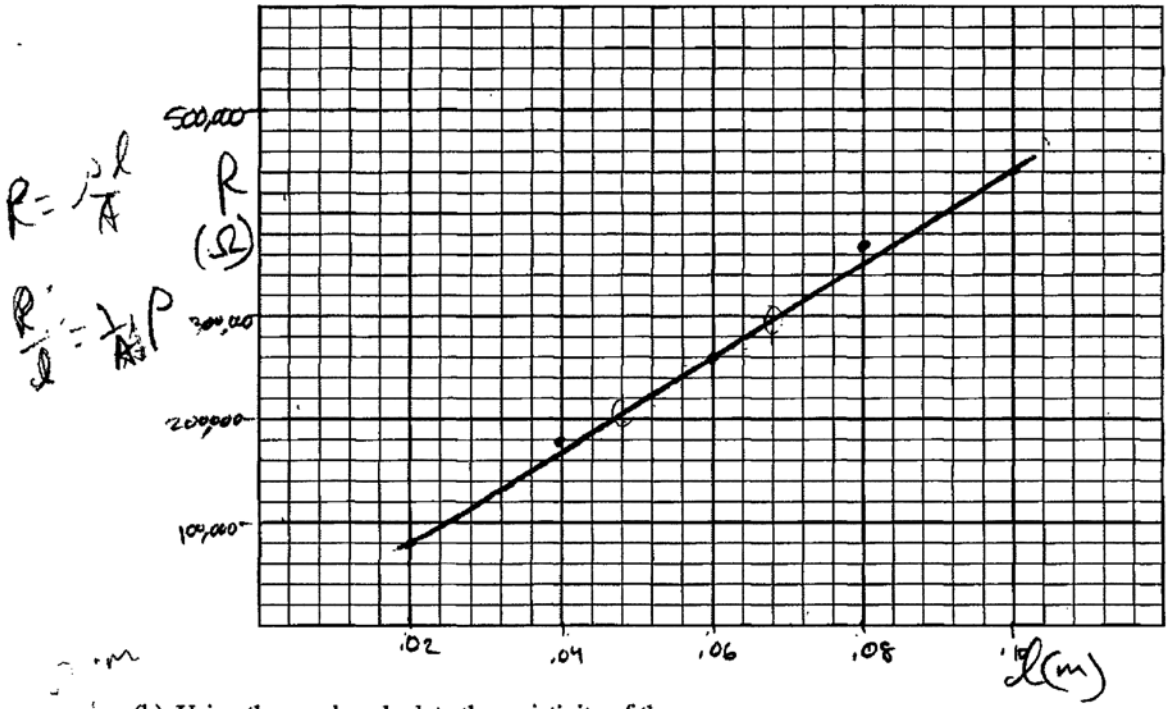


E&M. 2.

A physics student wishes to measure the resistivity of slightly conductive paper that has a thickness of 1.0×10^{-4} m. The student cuts a sheet of the conductive paper into strips of width 0.02 m and varying lengths, making five resistors labeled R1 to R5. Using an ohmmeter, the student measures the resistance of each strip, as shown above. The data are recorded below.

Resistor	R1	R2	R3	R4	R5
Length (m)	0.020	0.040	0.060	0.080	0.100
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



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

$\frac{R}{\ell} = \frac{1}{A}\rho$

(b) Using the graph, calculate the resistivity of the paper.

$\text{slope} = \frac{300{,}000 - 205{,}000}{.02} = 4{,}750{,}000$

$4{,}750{,}000 = \frac{\rho}{A} = \frac{\rho}{(.02\ \text{m})(1 \cdot 10^{-4}\ \text{m})}$ $\quad \rho = 2.38 \cdot 10^{-12}\ \Omega\text{m}$

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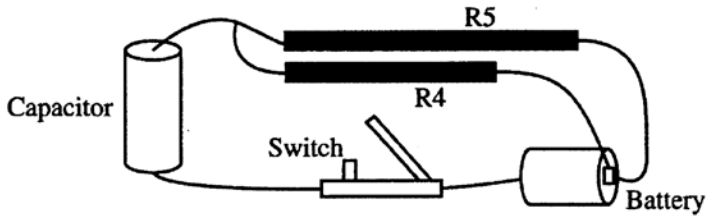


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

(c) Calculate the time constant of the circuit.

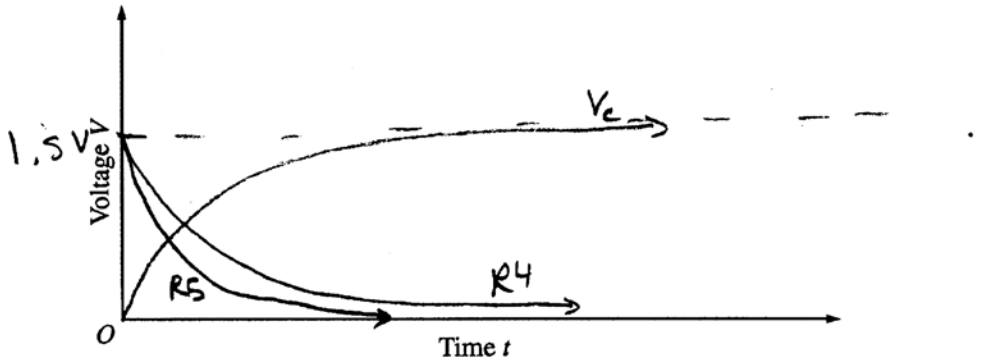
$\tau = RC$ $\quad R_{equiv} = \frac{R4 \cdot R5}{R4 + R5}$

$= (200{,}988\ \Omega)(10 \cdot 10^{-6}\ F) = \frac{(370{,}000\ \Omega)(740{,}000\ \Omega)}{(740{,}000 + 370{,}000)}$

$= 2.01\ \Omega \cdot F$ $\quad = 200{,}988\ \Omega$

$e^{-t/\tau}$

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.



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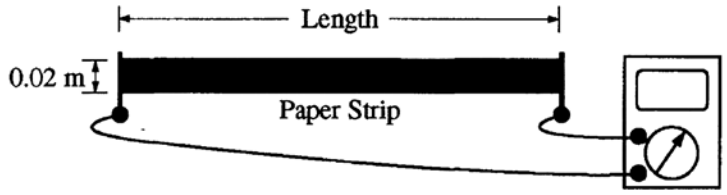
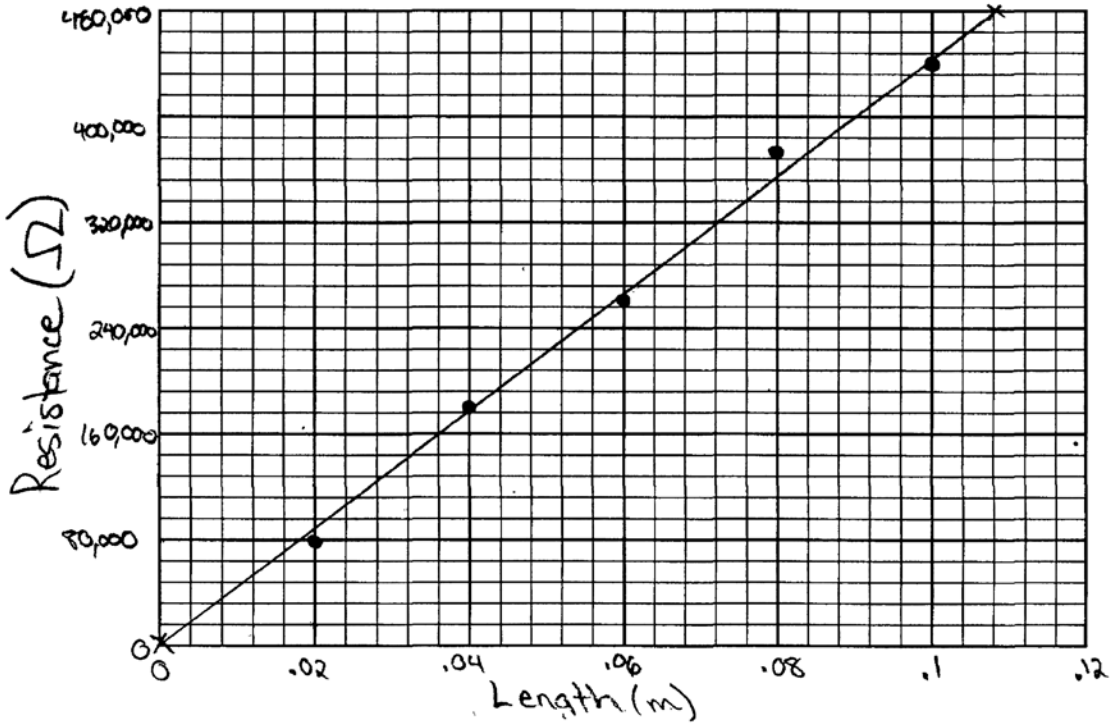


E&M. 2.

A physics student wishes to measure the resistivity of slightly conductive paper that has a thickness of 1.0×10^{-4} m . The student cuts a sheet of the conductive paper into strips of width 0.02 m and varying lengths, making five resistors labeled R1 to R5. Using an ohmmeter, the student measures the resistance of each strip, as shown above. The data are recorded below. $A_1 = 4\times10^{-4}$ $A_2 = 8\times10^{-4}$ $A_3 = 1.2\times10^{-3}$ $A_4 = 1.6\times10^{-3}$ $A_5 = 2\times10^{-3}$

Resistor	R1	R2	R3	R4	R5
Length (m)	0.020	0.040	0.060	0.080	0.100
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



(b) Using the graph, calculate the resistivity of the paper.

$\rho = \frac{R}{\ell} = \text{slope}$

$\rho = \frac{480{,}000}{.108}$

$\rho = 4.44\times10^{6}$

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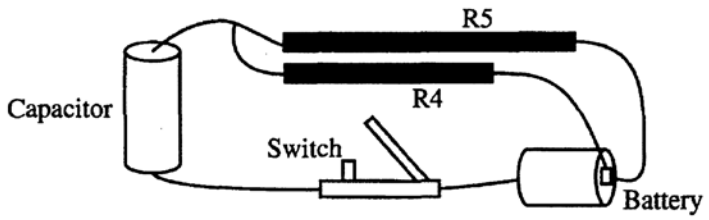


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

(c) Calculate the time constant of the circuit.

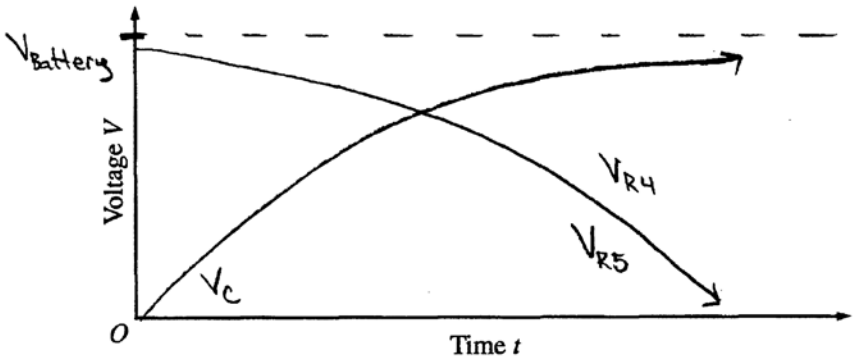
$\tau = R_{eq} C$

$= (R4 + R5)\, C$

$= (810000)(10 \times 10^{-6})$

$\tau = 8.1$

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.



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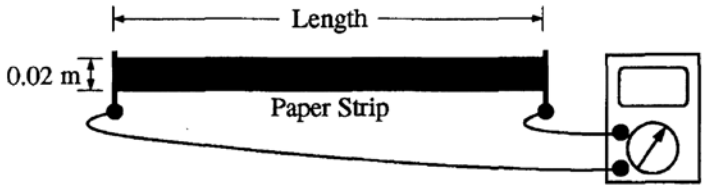

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Resistor	R1	R2	R3	R4	R5
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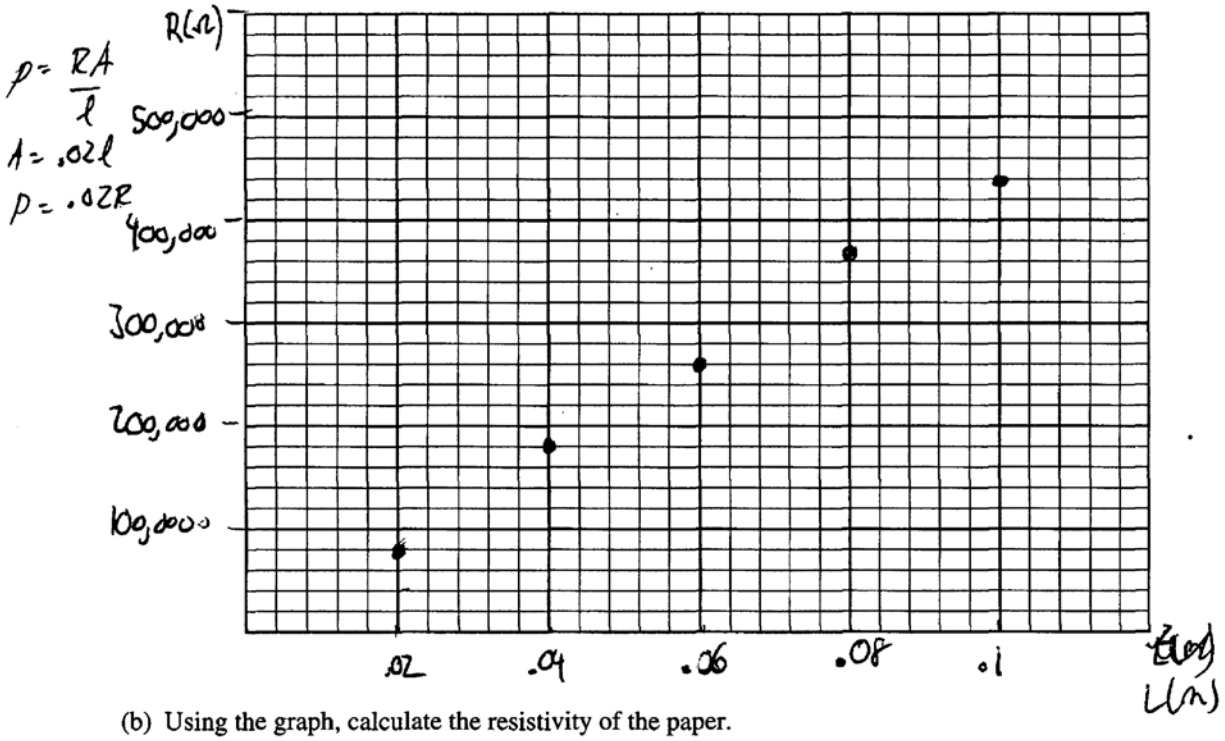
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



$\rho = \frac{RA}{\ell}$

$A = .02\ell$

$\rho = .02R$

(b) Using the graph, calculate the resistivity of the paper.

$\frac{\Delta R}{\Delta \ell} = \rho \quad \frac{440{,}000\Omega - 80{,}000\Omega}{.1 - .02} = 4.5 \times 10^{6}\ \Omega/m$

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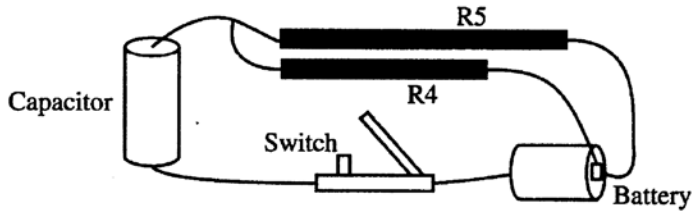


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

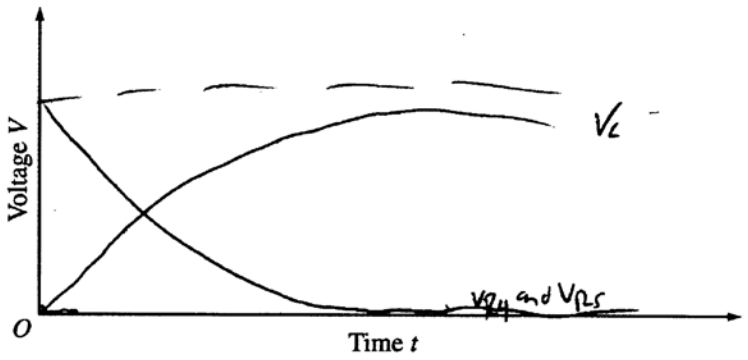
(c) Calculate the time constant of the circuit.

$V_0 - IR_5 - Q/C = 0$

$V_0 - IR_4 - Q/C = 0$

$\tau = 1/RC$

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.



AP® PHYSICS C: ELECTRICITY AND MAGNETISM
2012 SCORING COMMENTARY

Question 2

Overview

This question assessed students' understanding of electric resistivity of materials and resistor-capacitor (RC) circuits. To demonstrate their knowledge about electric resistivity, students were asked to plot a linear graph from which the resistivity of a substance could be determined. To demonstrate their knowledge about RC circuits, students were asked to calculate the time constant and sketch the voltage across the capacitor and each resistor as a function of time.

Sample: E2-A
Score: 13

The graph in part (a) earned full credit. Notice the two circles on the graph. These were not necessary, but they do show the reader the two points that are used for calculating slope, which is helpful. In part (b) 1 point was lost because the answer for the resistivity is incorrect. Full credit was awarded in part (c). One point was lost in part (d) because the two resistor voltages are not equal.

Sample: E2-B
Score: 9

The graph in part (a) earned full credit. One point was awarded in part (b) for calculating the slope from the best-fit line, but the student does not show the equation for calculating resistivity, and the answer is incorrect. In part (c) 1 point was earned for writing the expression for the RC time constant. One point was lost in part (d) because the two resistor voltages have the wrong shape.

Sample: E2-C
Score: 6

In part (a) only 3 points were earned because there is no best-fit line. No credit was earned in part (b) because the student uses data points to calculate slope instead of points from a best-fit line. No points were awarded in part (c). In part (d) the work is sloppy, but it earned 3 points; 1 point was lost for not labeling the asymptote.