2017

AP® CollegeBoard

AP Physics 2: Algebra-Based

Sample Student Responses and Scoring Commentary

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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 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.

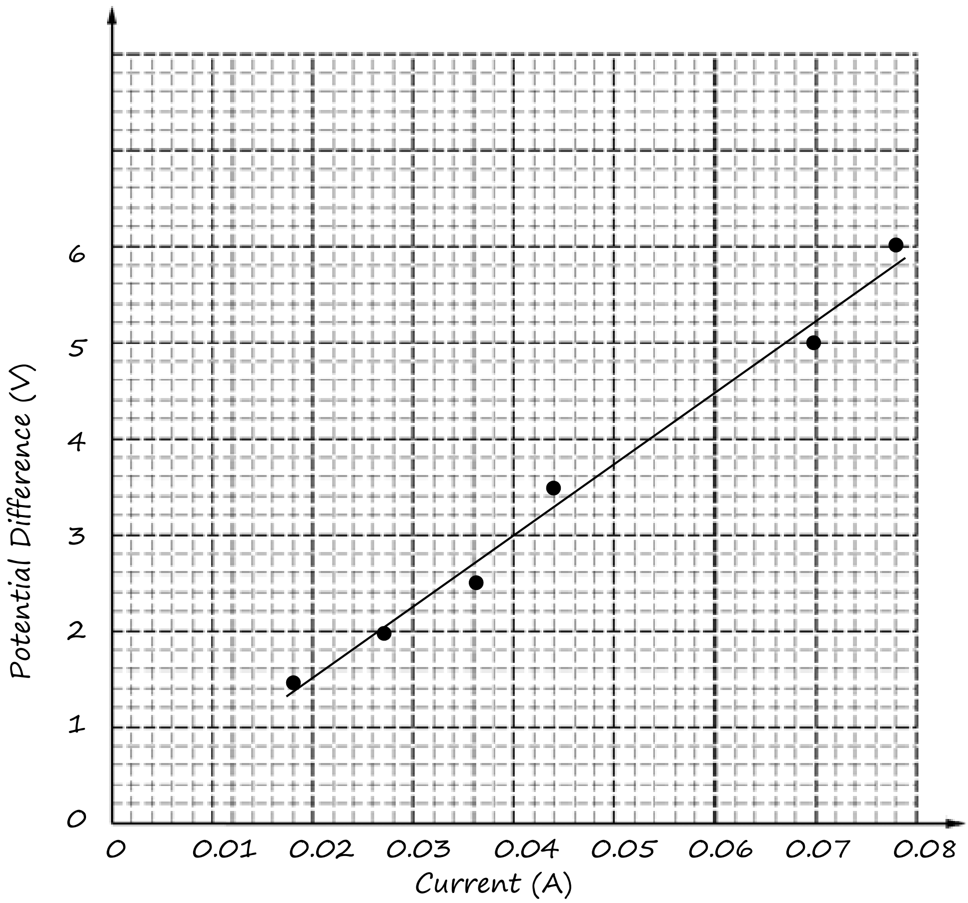
Question 2

12 points total	**Distribution of points**
(a)	
i. 5 points	
For drawing a circuit with the battery, rod, and ammeter in series (rods can be drawn to look like rods, or schematically as resistors)	1 point
For drawing the voltmeter parallel to the rod, or indicating that the setting on the power supply will be used	1 point
For measuring potential difference and current for a rod	1 point
For measuring the length and diameter of a rod	1 point
For including multiple trials with appropriate controls Examples: 1) Use one rod and apply different potential differences 2) Use different rods	1 point
ii. 2 points	
For graphing appropriate quantities whose slope can be used to calculate resistance directly or indirectly	1 point
For correctly stating how the slope relates to the resistivity	1 point

Question 2 (continued)

Distribution of points

(b) 3 points



For plotting the data on the graph with potential difference on one axis and current on the other, labeled with units, using a reasonable scale	1 point
For a clearly shown calculation of slope from a reasonable best-fit line	1 point
For a correct answer with units Acceptable range is $70 - 79\ \Omega$.	1 point

For a graph of I as a function of V, the slope should end up near $0.013\ \Omega^{-1}$ and the resistance is the inverse

For a graph of V as a function of I, the slope should end up near $74\ \Omega$ and equals the resistance

For the example shown above

$$\text{slope} = \frac{(5.8 - 2.4)\ \text{V}}{(0.078 - 0.032)\ \text{A}} = 73.9\ \Omega$$

Question 2 (continued)

Distribution of points

(c)

i. 1 point

For indicating that the internal resistance of the power supply will not affect the data acquired, with correct reasoning — 1 point

Example: Because potential difference is measured across each rod, $\Delta V/I$ is not affected by the internal resistance of the battery.

ii. 1 point

For indicating either: — 1 point

The students should be concerned because a change in temperature causes a change in the resistance or resistivity.

OR

The students should not be concerned because any change in resistivity as the temperature increases is small compared to measurement error.

2. (12 points, suggested time 25 minutes)

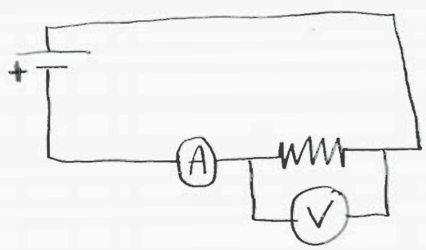
A group of students is given several long, thick, cylindrical conducting rods of the same unknown material with various lengths and diameters and asked to experimentally determine the resistivity of the material using a graph. The available equipment includes a voltmeter, an ammeter, connecting wires, a variable-output DC power supply, and a metric ruler.

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

(a)

i. Describe a procedure the students could use to collect the data needed to create the graph, including the measurements to be taken and a labeled diagram of the circuit to be used. Include enough detail that another student could follow the procedure and obtain similar data.

Draw a labeled diagram here.



A = ammeter (connected in series)

V = voltmeter (connected in parallel)

+ = DC power supply.

MM = conducting rods

Write your procedure here.

Build a circuit such that an ammeter is connected in series with the conducting rods, connected by wires to a variable output DC power supply. Connect a voltmeter in parallel with the conducting rods, as shown above. Set the output on the power supply to a set value such as 5 V and hold this constant for the duration of the experiment. Connect each conducting rod into the circuit one at a time. Each time, measure the voltage drop across the rod using the voltmeter and the current in the circuit using the ammeter. Record these values. Now remove the rod from the circuit and measure and record the length and radius of each rod. Repeat this process with at least 4 additional rods. (All measurements for length and radius should be made in meters, current should be measured in Amps and voltage drop in volts.)

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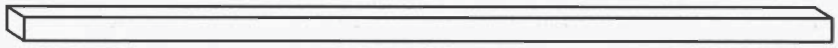
ii. Describe how the data could be graphed in a way that is useful for determining the resistivity of the material. Describe how the graph could be analyzed to calculate the resistivity.

From Kirchoff's Laws, the voltage drop across a resistor is $V=IR$. Since the conducting rods act as resistors, we can calculate the Resistance of the rod as V/I, both of which were previously measured (V = voltage drop measured by voltmeter, I = current, measured by ammeter). We also know that R can be given by $\rho\frac{l}{A}$, where ρ is resistivity, l is the length of the resistive material, and A is its cross-sectional area. We previously measured l, and A can be calculated using πr^2, using the measured values for radius. We can equate our experimental measurement for R (V/I) with the calculated R ($\rho\frac{l}{A}$) to obtain $\frac{V}{I} = \rho\frac{l}{A}$. If we plot V/I on the y axis as a function of l/A on the x-axis, the slope of the line of best fit should equal ρ and yield the experimental calculation for the resistivity of the material.

Question 2 continues on the next 2 pages.

GO ON TO THE NEXT PAGE.

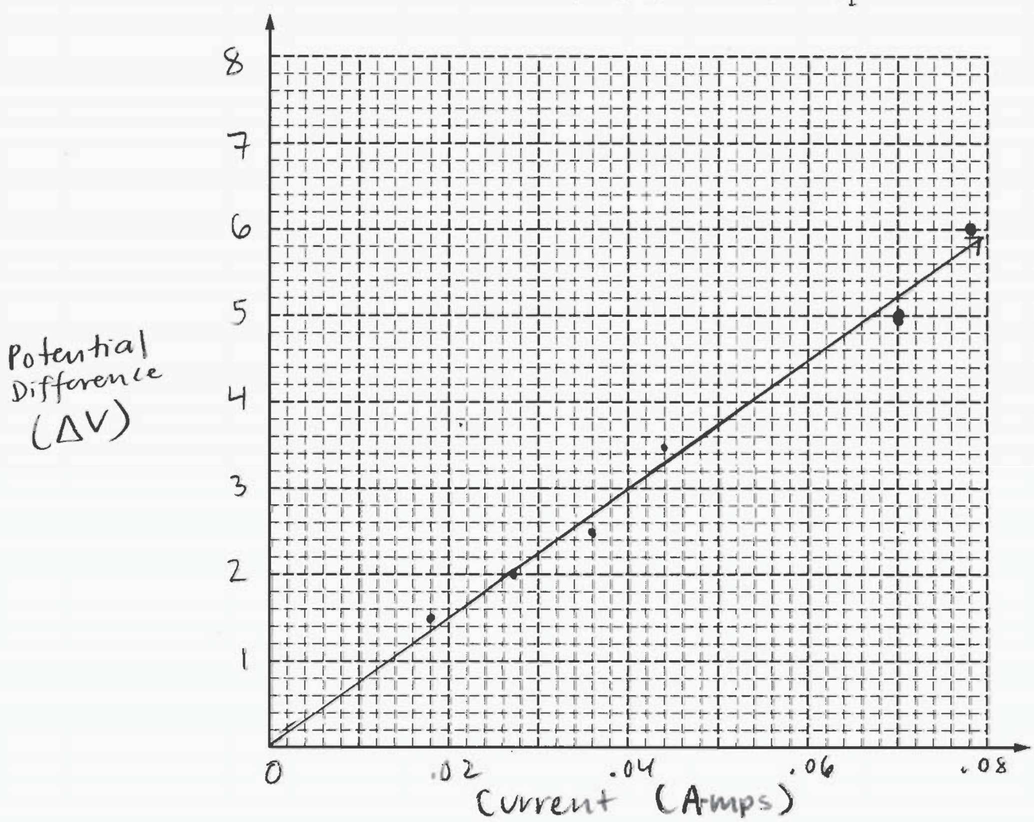
The students are now given a rectangular rod of the material, as shown below, whose dimensions are not known. The students are asked to experimentally determine the resistance of the rod. They obtain the data in the table below for the potential difference ΔV across the rod and the current I in it.



ΔV (V)	6.0	5.0	3.5	2.5	2.0	1.5
I (A)	0.078	0.070	0.044	0.036	0.027	0.018

(b) On the axes below, plot the data so that the resistance of the rectangular rod can be determined from a best-fit line. Label and scale the axes. Use the best-fit line to determine the resistance of the rod, clearly showing your calculations.

$V = IR$ $\quad R = V/I$



$V = IR \quad R = \text{slope}$

$m = \frac{\Delta Y}{\Delta X}$ two points on the line: (.04, 3) and (.008, .6)

$$\frac{3 - .6}{.04 - .008} = \frac{2.4}{.032} = 75$$

$$\boxed{\text{Resistance} = 75\ \Omega}$$

GO ON TO THE NEXT PAGE.

(c) After completing their calculations, the students begin to consider the factors that might have produced uncertainties in their results. $V = IR$

i. The students realize that they did not take into account the internal resistance of the power supply. Briefly describe how this would affect their value of the resistance of the rectangular rod. Explain your reasoning. It has no effect – the voltage drop across the rod was measured as well as the current through it, therefore R can be calculated using $V = IR$. Since the students measure ΔV across the resistor and not the circuit

ii. The students realize that they did not take into account a possible change in the temperature of the cylindrical rods. Should the students be concerned about this? Explain why or why not.

NO – any effects from change in temperature are minimal and would not drastically affect the results.

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2. (12 points, suggested time 25 minutes)

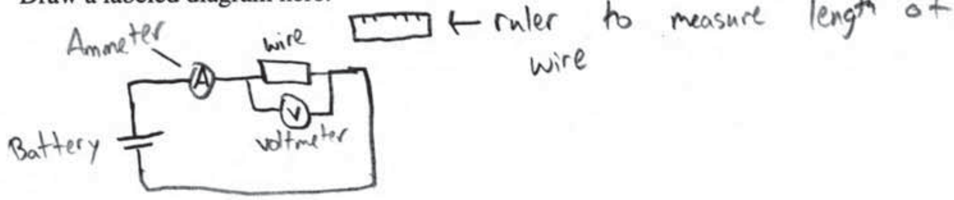
A group of students is given several long, thick, cylindrical conducting rods of the same unknown material with various lengths and diameters and asked to experimentally determine the resistivity of the material using a graph. The available equipment includes a voltmeter, an ammeter, connecting wires, a variable-output DC power supply, and a metric ruler.

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

(a)

i. Describe a procedure the students could use to collect the data needed to create the graph, including the measurements to be taken and a labeled diagram of the circuit to be used. Include enough detail that another student could follow the procedure and obtain similar data.

Draw a labeled diagram here.



Write your procedure here.

Attach a wire to the circut above in series with an ammeter and in parrallel with a voltmeter. Use the ruler to record the ~~wire~~ diameter and length of the wire. Convert them to meters. Record them and turn on the battery to 12V. Record the current value given by the ammeter. ~~Take the~~ Record the potential difference value. Use V=IR to solve for resistence. With everything known but p (resistivity) you can find the unknown resistivity of the material. Graph the potential differenc on the x-axis and the resistance on the y-axis.

GO ON TO THE NEXT PAGE.

ii. Describe how the data could be graphed in a way that is useful for determining the resistivity of the material. Describe how the graph could be analyzed to calculate the resistivity.

The resistivity is por~~p~~portional to the Resistance and the y-intercept will give the risistivity value.

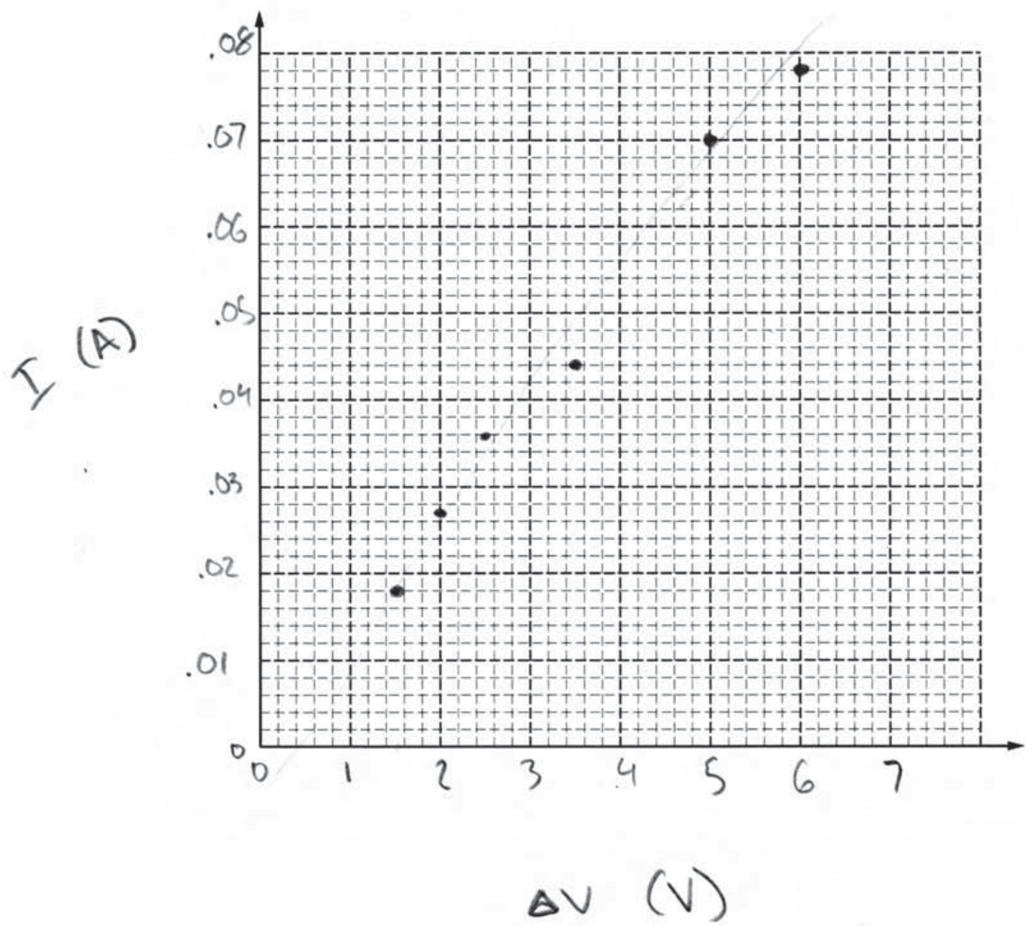
Question 2 continues on the next 2 pages.

GO ON TO THE NEXT PAGE.

The students are now given a rectangular rod of the material, as shown below, whose dimensions are not known. The students are asked to experimentally determine the resistance of the rod. They obtain the data in the table below for the potential difference ΔV across the rod and the current I in it.

ΔV (V)	6.0	5.0	3.5	2.5	2.0	1.5
I (A)	0.078	0.070	0.044	0.036	0.027	0.018

(b) On the axes below, plot the data so that the resistance of the rectangular rod can be determined from a best-fit line. Label and scale the axes. Use the best-fit line to determine the resistance of the rod, clearly showing your calculations.



$y = .07 \cdot x$

Resistance ≈ 75 Ω

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(c) After completing their calculations, the students begin to consider the factors that might have produced uncertainties in their results.

i. The students realize that they did not take into account the internal resistance of the power supply. Briefly describe how this would affect their value of the resistance of the rectangular rod. Explain your reasoning. An unnacounted for internal resistance would have increased their experimental value. They would have assumed all of the resistance came from the ~~[illegible]~~ rod when it really didn't.

ii. The students realize that they did not take into account a possible change in the temperature of the cylindrical rods. Should the students be concerned about this? Explain why or why not.

No. Resistance depends on P (resistivity), l (length) and A (area). Resisters heat up to resist, but heat does not affect the resistance of the wire.

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2. (12 points, suggested time 25 minutes)

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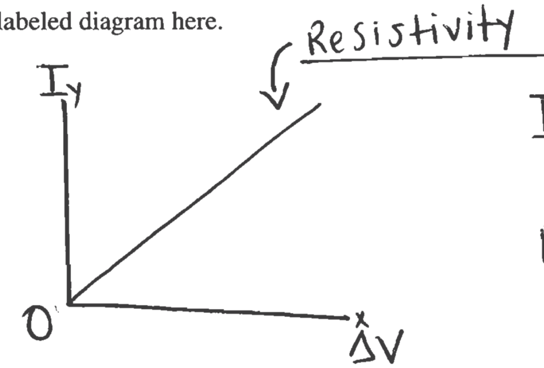
(a)

i. Describe a procedure the students could use to collect the data needed to create the graph, including the measurements to be taken and a labeled diagram of the circuit to be used. Include enough detail that another student could follow the procedure and obtain similar data.

Draw a labeled diagram here.



$I = \frac{\Delta V}{R}$

$R = \frac{\Delta V}{I}$

Write your procedure here.

- Gather your materials
- Calculate for the current & Potential difference.
- Once you have all your Variables graph them in a graph like the one shown above.
- witheach points given, divide current from Potential difference to find resistivity in each Conducting rod.

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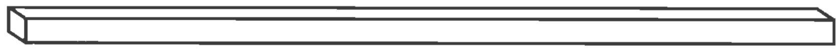
ii. Describe how the data could be graphed in a way that is useful for determining the resistivity of the material. Describe how the graph could be analyzed to calculate the resistivity.

For each rod Calculate ΔV & I then plot them in the graph. Once you have all the Variables start using $R = \frac{\Delta V}{I}$ to find resistivity in each one.

Question 2 continues on the next 2 pages.

GO ON TO THE NEXT PAGE.

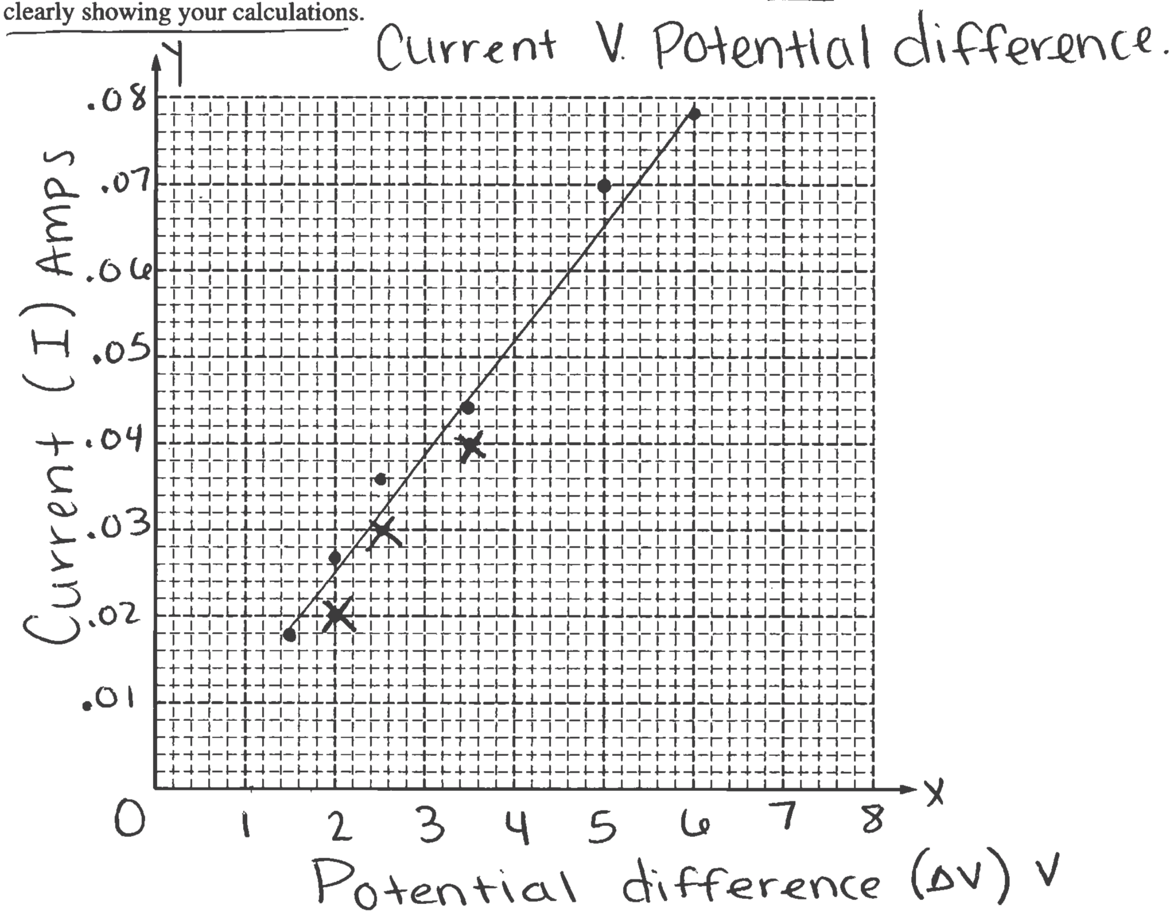
The students are now given a rectangular rod of the material, as shown below, whose dimensions are not known. The students are asked to experimentally determine the resistance of the rod. They obtain the data in the table below for the potential difference ΔV across the rod and the current I in it.



ΔV (V)	6.0	5.0	3.5	2.5	2.0	1.5
I (A)	0.078	0.070	0.044	0.036	0.027	0.018

(b) On the axes below, plot the data so that the resistance of the rectangular rod can be determined from a best-fit line. Label and scale the axes. Use the best-fit line to determine the resistance of the rod, clearly showing your calculations.

$R = \frac{\Delta V}{I}$



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(c) After completing their calculations, the students begin to consider the factors that might have produced uncertainties in their results.

i. The students realize that they did not take into account the internal resistance of the power supply. Briefly describe how this would affect their value of the resistance of the rectangular rod. Explain your reasoning.

Internal resistance of the power supply can decrease the value of the resistance of the rectangular rod.

ii. The students realize that they did not take into account a possible change in the temperature of the cylindrical rods. Should the students be concerned about this? Explain why or why not.

No, temperature is not a factor to take into consideration. It can in no way affect current value nor potential difference value. The equation $R = \frac{\Delta V}{I}$ also does not contain temperature.

Question 2

Overview

This question assessed learning objectives 1.E.2.1, 4.E.4.3, 4.E.5.3, 5.B.9.5, and 5.C.3.4.
The responses to this question were expected to demonstrate the following:

- The skill of drawing a circuit diagram with voltmeter and ammeter reasonably wired in.
- The skill of labeling axes with appropriate scale and plotting points, drawing a best-fit line, and calculating the slope from points on the line.
- The skill of planning an experiment to measure resistivity.
- The understanding of the relationship between resistance, resistivity, length, and cross-sectional area for a conductor.
- The understanding of Ohm's law.
- The skill of being aware of factors that may affect an experiment and explaining whether they should be of concern or not.

Sample: P2 Q2 A
Score: 11

This response describes the experiment and analysis in part (a) thoroughly and earned full credit of 7 points for parts (a)(i) and (a)(ii). Part (b) earned only 2 points because the unit of volt is not included in the label on the vertical axis of the graph. Instead ΔV is written in parenthesis where the unit would be expected. Both sections of part (c) contain correct answers and earned full credit of 2 points.

Sample: P2 Q2 B
Score: 6

In part (a)(i) a correct circuit is drawn and the procedure is correct except for not repeating with each rod or varying the potential difference for a single rod, so 4 points were earned. An incorrect graph of resistance as a function of potential difference is mentioned in this part, and (a)(ii) indicates that the resistivity is an intercept, so that part earned no credit. In part (b) the graph and final answer are correct, but there is no clear slope calculation, so 2 points were earned. Part (c) contains incorrect responses and earned no credit.

Sample: P2 Q2 C
Score: 1

Part (a)(i) has no circuit diagram. The response does not indicate measurements, referring to calculating current and potential difference. No credit was earned for this part. In part (a)(ii) there is again no connection to any experimental data, no use of the slope, and no relationship correctly connecting to the resistivity. Part (b) earned 1 point for labelling the axes and plotting the data. The response in part (c)(i) incorrectly claims that the resistance of the rod may decrease, and part (c)(ii) does not have a correct reason for neglecting temperature effects, so that part earned no credit.