2018

AP® CollegeBoard

AP Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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AP® PHYSICS
2018 SCORING GUIDELINES

General Notes About 2018 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 1 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 Course and Exam Description* and the *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 the 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 group of students prepare a large batch of conductive dough (a soft substance that can conduct electricity) and then mold the dough into several cylinders with various cross-sectional areas A and lengths ℓ. Each student applies a potential difference ΔV across the ends of a dough cylinder and determines the resistance R of the cylinder. The results of their experiments are shown in the table below.

Lab Station	$A\ (m^2)$	ℓ (m)	ΔV (V)	$R\ (\Omega)$	Example: $RA\ (\Omega \cdot m^2)$	Example: $\ell/A\ (m^{-1})$
1	0.00049	0.030	1.02	23.6	0.012	61
2	0.00049	0.050	2.34	31.5	0.015	102
3	0.00053	0.080	3.58	61.2	0.032	151
4	0.00057	0.150	6.21	105.0	0.060	263

(a) LO / SP: 1.E.2.1 / 4.1; 5.B.9.3 / 2.2; 5.C.3.2 / 4.1, 5.1
7 points

The students want to determine the resistivity of the dough cylinders.

i. 2 points

Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

Vertical Axis: ____________________ Horizontal Axis: ____________________

For quantities derived from R, ℓ, and A only		1 point
For choosing two quantities that, graphed together, can be used to determine the resistivity		1 point

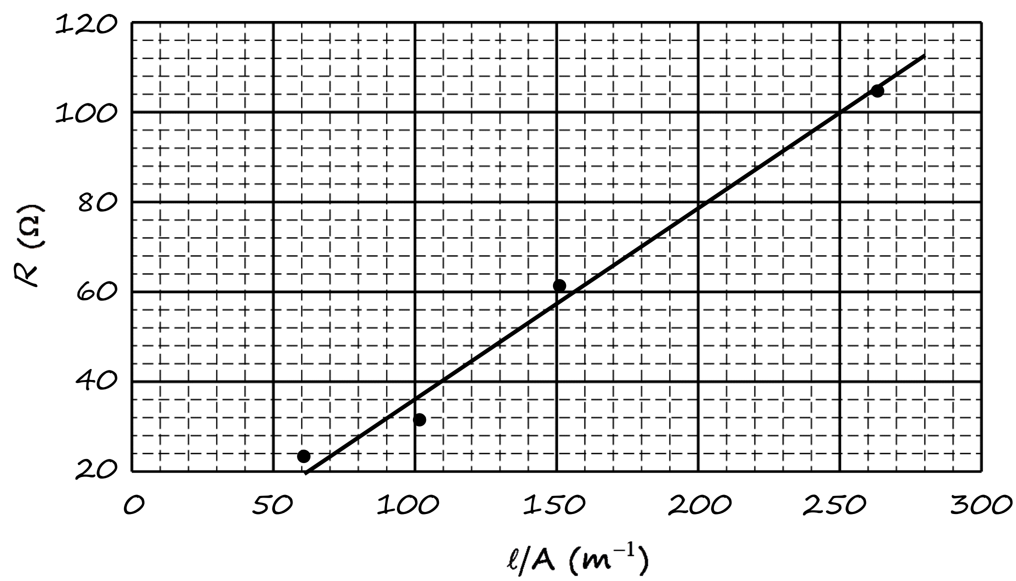
Question 2 (continued)

Distribution of points

(a) (continued)

ii. 3 points

On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



<u>Note</u>: The following points can be earned only if the graphed points correspond to the quantities chosen in (a)(i).	
For a linear scale where the plotted data uses at least half the grid	1 point
For labeling both axes, with units as appropriate	1 point
For data points plotted that represent the appropriate trend based on chosen quantities <u>Note</u>: The appropriate trend depends on the choice of graphed quantities and may be e.g., linear, inversely proportional, etc.	1 point

Question 2 (continued)

Distribution of points

(a) (continued)

iii. 2 points

Use the above graph to estimate a value for the resistivity of the dough cylinders.

For correctly using the slope of the graph to find the resistivity or a statement that a calculator was used to find the appropriate value from the graph		1 point
For a correct value of the resistivity $\rho = 0.42\ \Omega{\bullet}\text{m}\ (\pm 0.03)$ calculated from graph or data		1 point

(b) LO / SP: 1.E.2.1 / 4.1
1 point

Another group of students perform the experiment described in part (a) but shape the dough into long rectangular shapes instead of cylinders. Will this change affect the value of the resistivity determined by the second group of students?
____ Yes ____ No
Briefly justify your reasoning.

Correct answer: "No" <u>Note</u>: If the wrong selection is made, the explanation is not graded.		
For indicating that resistivity only depends on material, not shape		1 point

(c) LO / SP: 1.E.2.1 / 4.1; 5.B.9.2 / 4.2; 5.B.9.3 / 2.2; 5.C.3.2 / 4.1, 4.2; 5.C.3.3 / 1.4, 2.2
4 points

Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.

For explicitly or implicitly controlling all variables (e.g., length and area) except for temperature		1 point
For a plausible way to change the temperature of the dough		1 point
For indicating that the temperature will be varied		1 point
For a valid and feasible experiment in which resistance, OR voltage and current, are appropriately measured		1 point
Example: Make two dough cylinders of the same length and cross-sectional area. Keep one cylinder at room temperature, and heat the other cylinder on a hot plate to 30°C (measured with a thermometer). Apply the same voltage to each cylinder (measured with a voltmeter), and measure the current through each cylinder with an ammeter.		

Question 2 (continued)

Learning Objectives (LO)

LO 1.E.2.1: The student is able to choose and justify the selection of data needed to determine resistivity for a given material. [See Science Practice 4.1]

LO 5.B.9.2: The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ($\Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. [See Science Practices 4.2, 6.4, and 7.2]

LO 5.B.9.3: The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [See Science Practices 2.2, 6.4, and 7.2]

LO 5.C.3.2: The student is able to design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. [See Science Practices 4.1, 4.2, and 5.1]

LO 5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [See Science Practices 1.4 and 2.2]

2. (12 points, suggested time 25 minutes)

A group of students prepare a large batch of conductive dough (a soft substance that can conduct electricity) and then mold the dough into several cylinders with various cross-sectional areas A and lengths ℓ. Each student applies a potential difference ΔV across the ends of a dough cylinder and determines the resistance R of the cylinder. The results of their experiments are shown in the table below.

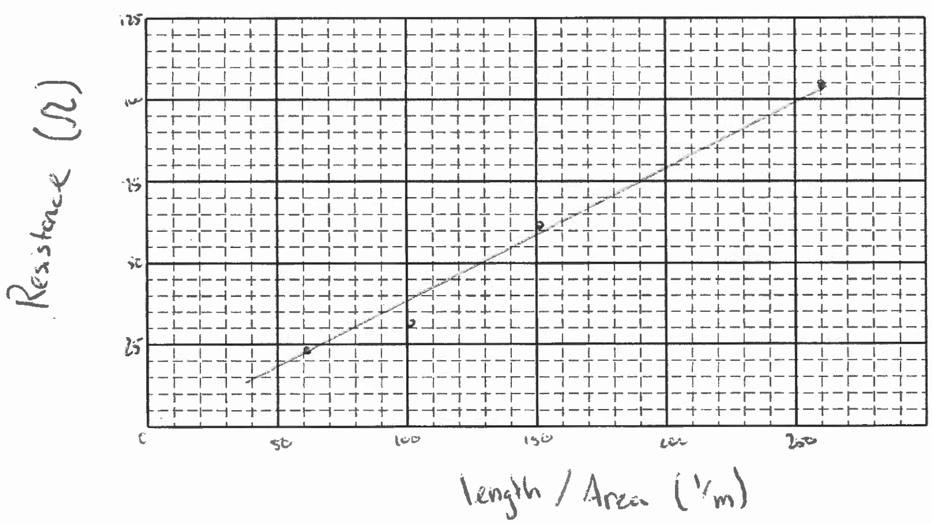
Dough Cylinder	A (m^2)	ℓ (m)	ΔV (V)	R (Ω)	ℓ/A 1/m	
1	0.00049	0.030	1.02	23.6	61.2	
2	0.00049	0.050	2.34	31.5	102.0	
3	0.00053	0.080	3.58	61.2	150.9	
4	0.00057	0.150	6.21	105	263.2	

(a) The students want to determine the resistivity of the dough cylinders.

i. Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

Vertical Axis: Resistance　　　Horizontal Axis: Length (ℓ) / Area (A)

ii. On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



iii. Use the above graph to estimate a value for the resistivity of the dough cylinders.

slope = resistivity　　$\frac{\text{rise}}{\text{run}} = \frac{105 - 23.6}{263.2 - 61.2} = \frac{81.4}{202}$

$= .403$ Ωm

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(b) Another group of students perform the experiment described in part (a) but shape the dough into long rectangular shapes instead of cylinders. Will this change affect the value of the resistivity determined by the second group of students?

____ Yes _X_ No

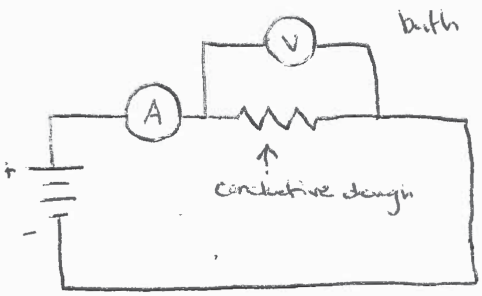
Briefly justify your reasoning.

Resistivity is a property of the material, not the shape it is in. Since the dough does not change, the resistivity won't either.

(c) Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.

A circuit like the one pictured below will be set up, with the voltage source being constant, perhaps a 9V Battery. An ammeter should be wired in series and a voltmeter should be wired in parallel with the dough. This setup will allow the student to see the Resistance of the dough because Voltage will be known (via Battery label + voltmeter reading) and Current will be known (via ammeter reading), and the relationship V = IR can be used. While maintaining constant length and cross-sectional area, the dough should be heated or cooled, or both, which can be done in a variety of ways, depending on available resources. An ice water bath could cool the dough, or a hot plate could heat it up. The student should get measurements of current and voltage several times after either heating the dough up or cooling it down, as it traverses a range of Temps to return to room temp. While a thermometer could help determine more precisely resistivity at each temp. it is not needed b/c it is sure the dough is changing temp. The relationship ρ(resistivity) = $\frac{RA}{l}$ is used now.

Since A and l are constant, any change in R, found in the method described earlier, will signify a change in resistivity.



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2. (12 points, suggested time 25 minutes)

A group of students prepare a large batch of conductive dough (a soft substance that can conduct electricity) and then mold the dough into several cylinders with various cross-sectional areas A and lengths ℓ. Each student applies a potential difference ΔV across the ends of a dough cylinder and determines the resistance R of the cylinder. The results of their experiments are shown in the table below.

Dough Cylinder	A (m^2)	ℓ (m)	ΔV (V)	R (Ω)	R · A	
1	0.00049	0.030	1.02	23.6	.011564	
2	0.00049	0.050	2.34	31.5	.015435	
3	0.00053	0.080	3.58	61.2	.032436	
4	0.00057	0.150	6.21	105	.05985	

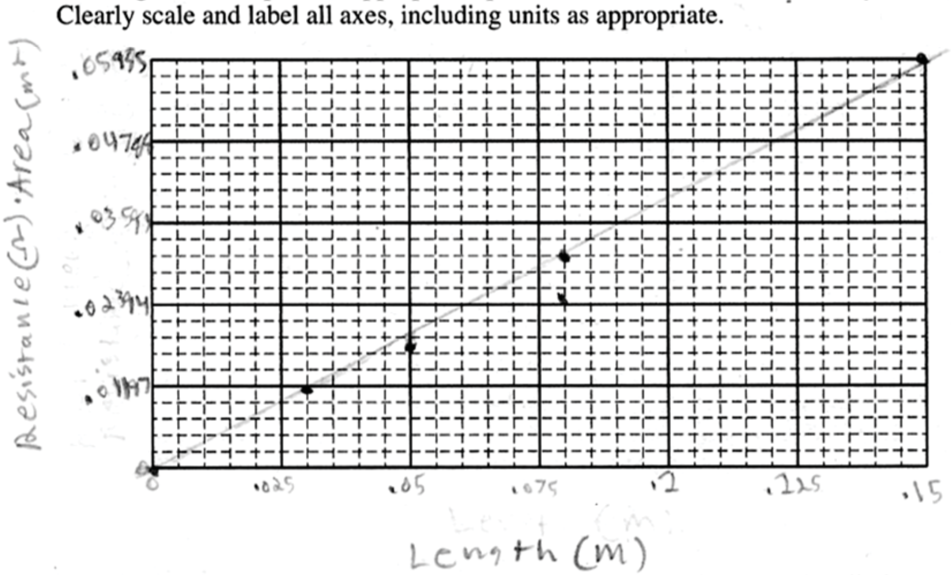
(a) The students want to determine the resistivity of the dough cylinders.

i. Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

Vertical Axis: RA ($\Omega \cdot m^2$) Horizontal Axis: ℓ (m)

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

ii. On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



iii. Use the above graph to estimate a value for the resistivity of the dough cylinders.

$\rho = \frac{RA}{l} = \frac{.05985}{.15} = .399\ \Omega m$

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(b) Another group of students perform the experiment described in part (a) but shape the dough into long rectangular shapes instead of cylinders. Will this change affect the value of the resistivity determined by the second group of students?

_✓_ Yes ____ No

Briefly justify your reasoning.

The area would change, the formula for the area of a cylinder and rectangule are diffrent which will resut in a diffrent ressistivity.

(c) Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.

The eqipment that would be used to determine if the resistivity of the dough cylinders change based on temperature would be a meterstick (for length) and a thermoter (for temp). Set up 4 exactly same dough cylinders (same length and area) and put each one under different temperatures. The thermoter can be used to determine the temperature where each dough will be placed. After waiting a certain time - about a couple of hours - Check if the resistivity has changed.

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2. (12 points, suggested time 25 minutes)

A group of students prepare a large batch of conductive dough (a soft substance that can conduct electricity) and then mold the dough into several cylinders with various cross-sectional areas A and lengths ℓ. Each student applies a potential difference ΔV across the ends of a dough cylinder and determines the resistance R of the cylinder. The results of their experiments are shown in the table below.

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

R – resistance
ρ – resistivity
ℓ – length
A – area

Dough Cylinder	A (m^2)	ℓ (m)	ΔV (V)	R (Ω)	R × A	
1	0.00049	0.030	1.02	23.6	0.012	
2	0.00049	0.050	2.34	31.5	0.154	
3	0.00053	0.080	3.58	61.2	0.032	
4	0.00057	0.150	6.21	105	0.060	

0.4
3.08
0.4
0.4

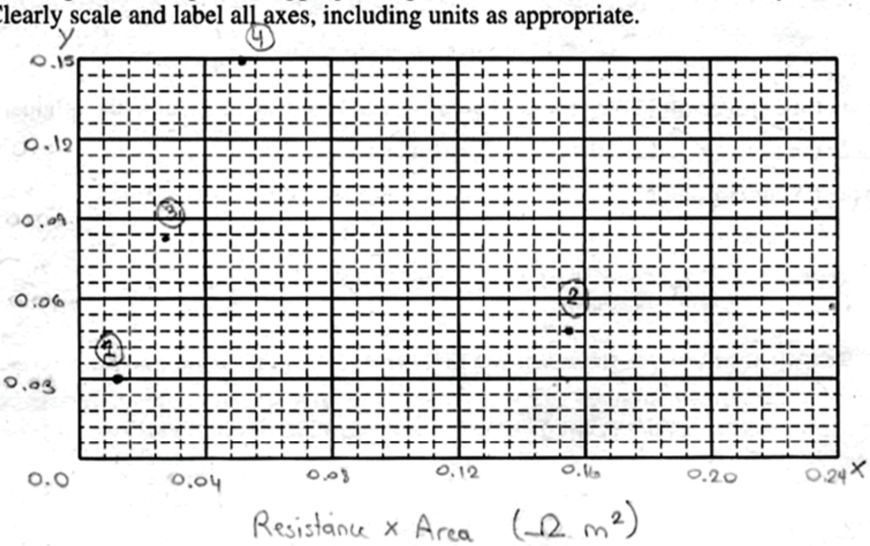
(a) The students want to determine the resistivity of the dough cylinders.

i. Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

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

Vertical Axis: Length (m) Horizontal Axis: Resistance × Area (Ω m^2)

ii. On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



iii. Use the above graph to estimate a value for the resistivity of the dough cylinders.

Based on the above graph, the resistivity of the dough cylinders is around 1.07 Ω m.

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(b) **Another group of students perform the experiment described in part (a) but shape the dough into long rectangular shapes instead of cylinders. Will this change affect the value of the resistivity determined by the second group of students?**

✓ **Yes** ____ **No**

Cylin $\pi r^2 h$

Ret lwh

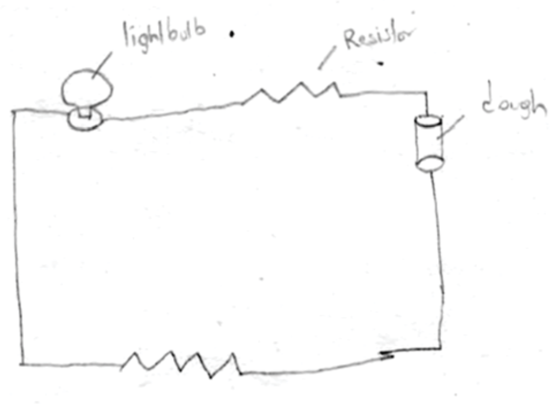
Briefly justify your reasoning.

With cylinders, they will have a greater area, meanwhile rectangle will have a less surface area. Having a greater surface area will make the resistivity value to be greater, yet depends on resistance and length of the object. The relationship between the surface area and resistivity are linearly proportional to each other.

(c) **Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.**

In order to determine if resistivity depends on temperature is to first off create a circuit that has a light bulb, a dough cylinder, wires, and resistors. First off, create a variety of dough cylinders to create at least five trials with different resistors. Second, set up the circuit for the trials to determine if resistivity. Have a thermometer to measure temperature of the dough. Have a variety of temperatures to determine if resistivity depends on the dough.

Diagram:



Question 2

Overview

This question assessed learning objectives 1.E.2.1, 5.B.9.2, 5.B.9.3, 5.C.3.2, and 5.C.3.3.

The responses to this question were expected to demonstrate the following:

- The ability to choose what quantities should be graphed so that the slope of the line will allow the unknown quantity to be found.
- The ability to correctly label axes of a graph with units.
- The ability to choose an appropriate linear scale for the axes of a graph.
- The ability to calculate the slope of the best-fit line using points on the line and not the data points that were individually plotted using a collection of data.
- The ability to convey knowledge about the intrinsic nature of resistivity.
- The ability to design an experiment with appropriate controls, identify variables and how to manipulate the variables in a physical setting with appropriate equipment, and to collect the necessary measurements in order to calculate the desired quantity/quantities.

Sample: P1 Q2 A
Score: 12

Part (a)(i) earned 2 points. The response earned 1 point because the derived quantities use only ℓ, R, and A. The response earned 1 point for choosing two quantities, R and ℓ/A, that can be used to determine the resistivity of the dough. Part (a)(ii) earned 3 points. The response earned 1 point for choosing a linear scale on both axes so the plotted data uses at least half of the available grid. The response earned 1 point for labeling the quantities and associated units plotted on the horizontal and vertical axes. The response earned 1 point for points plotted that represent the appropriate linear trend based on the two quantities that were chosen to be graphed. Part (a)(iii) earned 2 points: 1 point for correctly using the slope of the graph to algebraically solve for the resistivity, and 1 point for a correct value of the resistivity of the dough that is within the acceptable range of resistivity of $0.39\ \Omega\text{•m}$ to $0.45\ \Omega\text{•m}$. In part (b) 1 point was earned for selecting "No" and indicating that the resistivity of the dough depends only on the material of the dough and not its shape. The response in part (c) earned 4 points. The response earned 1 point for explicitly controlling for a constant voltage of the battery, constant length of the dough, and constant cross sectional area of the dough. The response earned 2 points for indicating that the temperature of the dough will be changed and for a plausible way to change the dough temperature (either an ice water bath or a hot plate). The response earned 1 point for a valid and feasible experiment in which the resistance could be determined by measuring the current through and potential difference across the dough cylinder.

Sample: P1 Q2 B
Score: 8

Part (a)(i) earned 2 points. The response earned 1 point because the derived quantities use only ℓ, R, and A. The response earned 1 point for choosing two quantities, $R\text{•}A$ and ℓ, that can be used to determine the resistivity of the dough. Part (a)(ii) earned 3 points. The response earned 1 point for choosing a linear scale on both axes so the plotted data uses at least half of the available grid. The response earned 1 point for labeling the quantities and associated units plotted on the horizontal and vertical axes. The response earned 1 point for points plotted that represent the appropriate linear trend based on the two quantities that were chosen to be graphed. In part (a)(iii) 1 point was earned for a resistivity value within the acceptable range, but 1 point was not earned because the slope of the graph is not used. In part (b) no (out of 1) points were earned because the incorrect answer "Yes" is selected. The response in part (c) earned 2 of 4 points. The response earned 1 point for controlling the length and

Question 2 (continued)

area and 1 point for indicating that the dough temperature will be changed. The response did not earn the remaining 2 points because there is no indication of how to change the temperature or any measurements that could be used to determine the resistance.

Sample: P1 Q2 C
Score: 4

Part (a)(i) earned 2 points. The response earned 1 point because the derived quantities use only ℓ, R, and A. The response earned 1 point for choosing two quantities, ℓ and $R \cdot A$, that can be used to determine the resistivity of the dough. In part (a)(ii) 1 of 3 points was earned for a linear scale and plotted data that uses at least half of the grid. The response did not earn 1 point because the vertical axis is not labelled. The response did not earn another point because the plotted data does not indicate the appropriate linear trend, owing to the incorrect data point near 0.16 $\Omega \cdot m^2$. In part (a)(iii) neither of the 2 possible points were earned because there is no indication of how the graph is used, and the resistivity value is incorrect. In part (b) no (out of 1) points were earned because the incorrect answer "Yes" is selected. The response in part (c) earned 1 of 4 points for indicating that a variety of temperatures will be used, but it does not indicate how the temperature would be varied, does not control for length and area, and does not indicated measurements that could be used to determine the resistance.