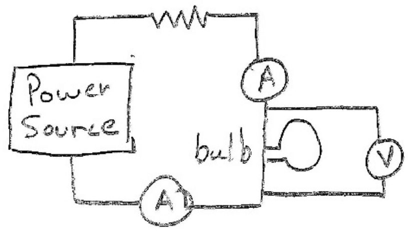
Question 2

12 points total | **Distribution of points**

(a) 5 points



For drawing a circuit in which the power source, resistor, and bulb are wired in series — 1 point

For connecting at least one ammeter in series with the bulb — 1 point

For connecting the voltmeter across the bulb in parallel — 1 point

For describing measurements that can plausibly be used to answer question 1 — 1 point

Example: Measure the current entering and leaving the bulb with ammeters connected in series on either side of the bulb.

For describing measurements that can plausibly be used to answer question 2 — 1 point

Example: Measure the potential difference across the bulb with a voltmeter connected in parallel with the bulb.

The response does not need to mention multiple measurements.

(b)

(i) 1 point

For describing an analytical method of using the data, and explaining how that analytical method can be used to answer question 1 — 1 point

Example: If the current is the same on both sides of the bulb, then the number of electrons per second entering and leaving the bulb is the same.

(ii) 1 point

For describing an analytical method of using the data, and explaining how that analytical approach can be used to answer question 2 — 1 point

Example: If the potential difference across the bulb is not zero, then electrons that leave the bulb have different electric potential energy than electrons that enter it.

Question 2 (continued)

	Distribution of points
(c)	
(i) 1 point	
For any of the following: Describing any changes to the circuit needed to have a setup that can plausibly be used to determine whether the bulb's resistance is constant as a function of current. Describing changes to a circuit that are not needed but do not impair the ability to determine whether the bulb's resistance is constant as a function of current. Correctly indicating that no changes are needed. Example based on circuit diagram in part (a): Remove one of the ammeters.	1 point
(ii) 1 point	
For describing any additional measurements needed to determine whether current varies linearly as a function of voltage, or indicating that none are needed if the appropriate multiple measurements are mentioned in part (a) or (c)(i) Example: Measure the current through the bulb and the potential difference across the bulb for multiple settings of the power source.	1 point
(d) 3 points	
For describing an analytical method in which data are represented or manipulated in some way that can plausibly be used to determine whether current varies linearly as a function of potential difference Examples: Graphing measurements of current as a function of potential difference Calculating the ratio of current to potential difference for multiple settings of the power source	1 point
For identifying that linearity is the relevant feature for determining whether the bulb is ohmic Examples: Evaluating whether a plot of current as a function of voltage is linear Evaluating whether the ratio of current to potential difference is constant	1 point
For describing a strategy for evaluating whether the conclusion of linearity is valid for a given data set taking into account the meter uncertainties Examples: Drawing error boxes that represent the uncertainties of the meters around each point and evaluating whether a straight line can be drawn that goes through all the error boxes. Indicating that small differences in the ratios could be due to uncertainty in the meters and would not discount the conclusion that the bulb is ohmic	1 point

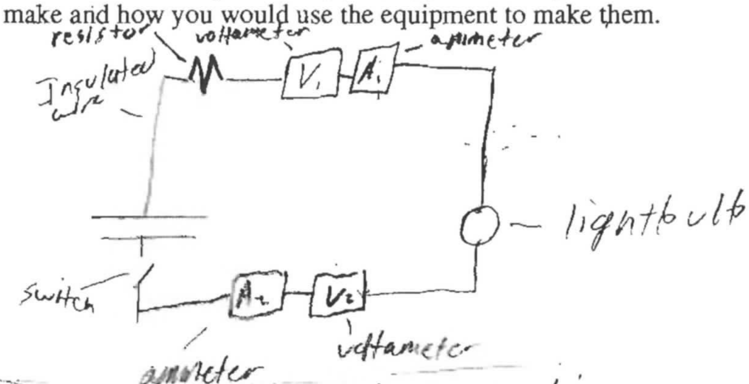
2. (12 points, suggested time 25 minutes)

Some students want to know what gets used up in an incandescent lightbulb when it is in series with a resistor: current, energy, or both. They come up with the following two questions.

(1) In one second, do fewer electrons leave the bulb than enter the bulb?
(2) Does the electric potential energy of electrons change while inside the bulb?

The students have an adjustable power source, insulated wire, lightbulbs, resistors, switches, voltmeters, ammeters, and other standard lab equipment. Assume that the power supply and voltmeters are marked in 0.1 V increments and the ammeters are marked in 0.01 A increments.

(a) Describe an experimental procedure that could be used to answer questions (1) and (2) above. In your description, state the measurements you would make and how you would use the equipment to make them. Include a neat, labeled diagram of your setup.



To answer questions 1 and 2, the students would use the voltameters and ammeters to measure the current and voltage of the circuit both before and after the lightbulb for 3 trials of 1 second. The students would record this information for calculations.

(b)

i. Explain how data from the experiment you described can be used to answer question (1) above.

The data from the experiment above can be used to answer question (1) by comparing the current in the circuit at the ammeter before and the ammeter after the lightbulb. If a discrepancy between the two measurements in each trial is found, fewer electrons may have left the lightbulb.

ii. Explain how data from the experiment you described can be used to answer question (2) above.

The data from the experiment above can be used to answer question (2) by comparing the voltage measured by the voltmeters placed before and after the lightbulb. If a discrepancy between the values from each voltmeter in a given trial is found, the electrical potential energy of the electrons may have changed while inside the bulb.

A lightbulb is nonohmic if its resistance changes as a function of current. Your setup from part (a) is to be used or modified to determine whether the lightbulb is nonohmic.

(c)

i. How, if at all, does the setup need to be modified?

The voltage of the adjustable power source must be varied for a given number of trials to create varying currents because current = $\frac{\text{voltage}}{\text{resistance}} = I = \frac{V}{R}$

ii. What additional data, if any, would need to be collected?

Additional data required would be a number of trials at given voltages from the adjustable power source. This would allow different data sets of voltage and current to be used to determine the resistance of the bulb.

(d) How would you analyze the data to determine whether the bulb is nonohmic? Include a discussion of how the uncertainties in the voltmeters and ammeters would affect your argument for concluding whether the resistor is nonohmic.

To determine whether the bulb is nonohmic, I would determine the resistances of the lightbulb in each trial according to the formula $I = \frac{\Delta V}{R}$ assuming that in series, no current is lost in the lightbulb (or circuit for that matter). If the resistance of the lightbulb is found to vary, it may be assumed to be nonohmic assuming the uncertainties in the voltmeters and ammeters did not affect the results. Because the uncertainties exist, however, If the change in voltage is less than or equal to .1 V, The conclusion as to whether or not the lightbulb is nonohmic cannot be verified using the given equipment.

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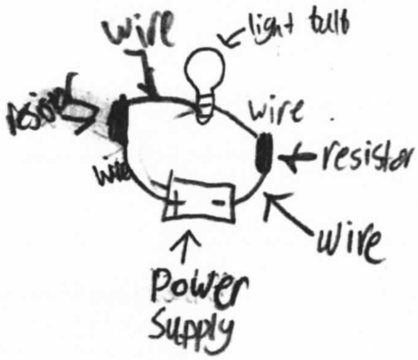
2. (12 points, suggested time 25 minutes)

Some students want to know what gets used up in an incandescent lightbulb when it is in series with a resistor: current, energy, or both. They come up with the following two questions.

(1) In one second, do fewer electrons leave the bulb than enter the bulb?
(2) Does the electric potential energy of electrons change while inside the bulb?

The students have an adjustable power source, insulated wire, lightbulbs, resistors, switches, voltmeters, ammeters, and other standard lab equipment. Assume that the power supply and voltmeters are marked in 0.1 V increments and the ammeters are marked in 0.01 A increments.

(a) Describe an experimental procedure that could be used to answer questions (1) and (2) above. In your description, state the measurements you would make and how you would use the equipment to make them. Include a neat, labeled diagram of your setup.



Using the set up drawn, the students could use voltmeters and ammeters to find both amps and volts both before and after the light bulb. With the amps, the students could convert it by multiplying by 6.024×10^{24} to find total electrons. And with the informations from the voltmeter, they could find if potential energy changes.

(b)

i. Explain how data from the experiment you described can be used to answer question (1) above.

Knowing how many amps there are before and after the bulb would allow the students to multiply amps by 6.024×10^{24} to see if the number of electrons went down.

ii. Explain how data from the experiment you described can be used to answer question (2) above.

Using the voltmeter for before and after the bulb would allow the students to see if there's a difference in potential energy before and after the bulb.

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A lightbulb is nonohmic if its resistance changes as a function of current. Your setup from part (a) is to be used or modified to determine whether the lightbulb is nonohmic.

(c)

i. How, if at all, does the setup need to be modified?

$R = IV$ I would need to add or remove a resistor for different trials to observe how it effects amps and resistance.

ii. What additional data, if any, would need to be collected?

I would need to collect data from a setup without the first resistor. I would need both amps and Volts.

(d) How would you analyze the data to determine whether the bulb is nonohmic? Include a discussion of how the uncertainties in the voltmeters and ammeters would affect your argument for concluding whether the resistor is nonohmic.

I would analyze to see if based on the current if the resistance changes. With two different values for current and volts I would need to see if $R_1 = R_2$. I would do this by doing $I_1 V_1 = R_1$ and $I_2 V_2 = R_2$. If $R_1 = R_2$, then the light bulb isn't nonohmic. Since votmeters round to the nearest 0.1V and ammeters round to the nearest 0.01A the results may be slightly off from their true values

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2. (12 points, suggested time 25 minutes)

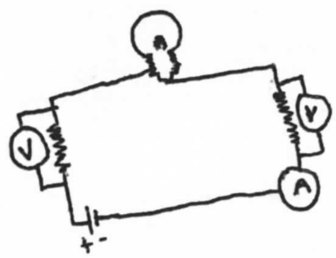
Some students want to know what gets used up in an incandescent lightbulb when it is in series with a resistor: current, energy, or both. They come up with the following two questions.

(1) In one second, do fewer electrons leave the bulb than enter the bulb?
(2) Does the electric potential energy of electrons change while inside the bulb?

The students have an adjustable power source, insulated wire, lightbulbs, resistors, switches, voltmeters, ammeters, and other standard lab equipment. Assume that the power supply and voltmeters are marked in 0.1 V increments and the ammeters are marked in 0.01 A increments.

(a) Describe an experimental procedure that could be used to answer questions (1) and (2) above. In your description, state the measurements you would make and how you would use the equipment to make them. Include a neat, labeled diagram of your setup.

The students should create a series including a lightbulb, power source, insulated wire, a resistors, ammeter, and voltmeter. Then they should calculate the current moving through the wire using $I = \frac{\Delta V}{R}$. Then calculate the electric potential energy of the resistor after the light bulb using $\Delta V = IR$



(b)

i. Explain how data from the experiment you described can be used to answer question (1) above.

The current when the battery switch is turned on will determine the amount of electrons entering the lightbulb. The current before reaching the battery again but ~~before~~ after the lightbulb will determine if the amount of electrons leaving the lightbulb is fewer, equal, or more than when they electrons entered the lightbulb

ii. Explain how data from the experiment you described can be used to answer question (2) above.

Calculate the electric potential energy before the lightbulb and after the light bulb to determine if the electric potential energy has changed.

A lightbulb is nonohmic if its resistance changes as a function of current. Your setup from part (a) is to be used or modified to determine whether the lightbulb is nonohmic.

(c)

i. How, if at all, does the setup need to be modified?

The setup does not need to be modified to determine whether the lightbulb is nonohmic or not.

ii. What additional data, if any, would need to be collected?

Current after the lightbulb.

(d) How would you analyze the data to determine whether the bulb is nonohmic? Include a discussion of how the uncertainties in the voltmeters and ammeters would affect your argument for concluding whether the resistor is nonohmic.

The students will have to analyze the current after the lightbulb. If the current has changed than the resistance will also, therefor the lightbulb will be nonohmic.

Question 2

Overview

The primary focus of this question was on experimental design and data analysis (using circuit elements and meters), and student knowledge of series circuits. Students were also asked to account for uncertainty in the measurement and to discuss how it affects their results.

Sample: P1Q2 A
Score: 11

Part (a) earned 4 points. The only point not earned is the one for connecting a voltmeter in parallel with the lightbulb. Parts (b)(i) and (b)(ii) earned full credit for a net of 2 points. Although the voltmeters are not connected correctly, in part (b)(ii) the student does show understanding that a potential difference is related to a change in electric potential energy. Parts (c)(i) and (c)(ii) also earned full credit for a net of 2 points. Adjusting the power source does not impair the usefulness of the circuit, and multiple trials for a variety of potential differences is useful additional data. Part (d) earned 3 points for full credit. The response describes calculating the resistance for each pair of data, indicates that a nonconstant ratio of potential difference to current would indicate that the bulb is nonohmic, and indicates that the uncertainties in the meters will affect the trend of the data.

Sample: P1Q2 B
Score: 8

Part (a) earned 3 points, since no meters are included in the circuit diagram. Parts (b)(i) and (b)(ii) earned full credit for a net of 2 points. Parts (c)(i) and (c)(ii) also earned full credit for a net of 2 points. Since the original circuit contained two resistors, removing one resistor would effectively alter the potential difference across the light bulb and allow for multiple measurements. Part (d) earned 1 point for indicating that the consistency of the resistance is the relevant feature to determine if the bulb is ohmic or nonohmic. The student has added resistors to the circuit, so it is not clear whether the student is measuring potential difference across a resistor or the bulb. The sentence on uncertainties does not address how they affect a conclusion.

Sample: P1Q2 C
Score: 3

Part (a) earned 2 points, for drawing a circuit in which the power source, resistor, and light bulb are in series and correctly connecting an ammeter. Part (b)(i) earned 1 point, and (b)(ii) earned no credit. The second explanation does not sufficiently address the data from the experimental procedure that can be used to answer question 2. Part (c)(i) earned 1 point for noting that no modification is needed. The circuit will still allow the bulb’s resistance to be tested. Part (c)(ii) earned no credit. Although the current needs to be measured, something in the circuit needs to be changed to provide multiple measurements. Part (d) earned no credit.