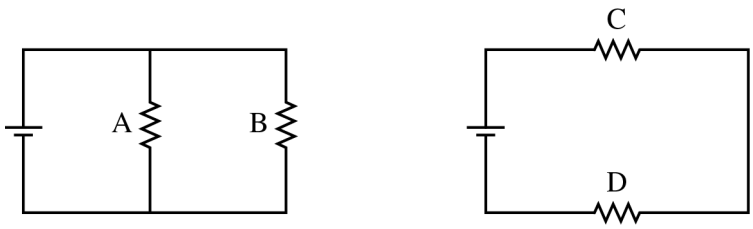
Begin your response to **QUESTION 2** on this page.



2. (12 points, suggested time 25 minutes)

Students perform an experiment with a battery and four resistors, A, B, C, and D. The resistance of resistors A and C is $R_A = R_C = R$. The resistance of resistors B and D is $R_B = R_D = 2R$. The students create the two circuits shown above and measure the potential differences ΔV_A, ΔV_B, ΔV_C, and ΔV_D across resistors A, B, C, and D, respectively.

(a) From greatest to least, rank the magnitudes of the potential differences across the resistors. Use "1" for the greatest magnitude, "2" for the next greatest magnitude, and so on. If any potential differences have the same magnitude, use the same number for their ranking.

____ΔV_A ____ΔV_B ____ΔV_C ____ ΔV_D

Justify your answer.

In another experiment, the students have a capacitor with unknown capacitance C_U. They want to determine C_U by using a battery of potential difference 4.5 V and several other capacitors of known capacitance. They create circuits with the battery, the unknown capacitor, and one of the capacitors of known capacitance. The students wait until the capacitors are fully charged and then record the potential difference ΔV_{known} across the known capacitor and the potential difference ΔV_U across the unknown capacitor. Their data are shown in the table on the following page.

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Known Capacitance of Capacitors (μF)	ΔV_{known} (V)	ΔV_U (V)		
200	0.91	3.53		
300	0.65	3.74		
400	0.51	3.95		
500	0.42	4.06		
600	0.36	4.17		

(b)

i. Calculate the amount of charge on the capacitor of known capacitance of 200 μF in the students' experiment.

ii. Briefly explain why the data in the table provide evidence that the capacitors are connected in series.

iii. Briefly explain why connecting the capacitors in parallel would not provide enough information to determine the capacitance of the unknown capacitor if the only measuring device available is a voltmeter.

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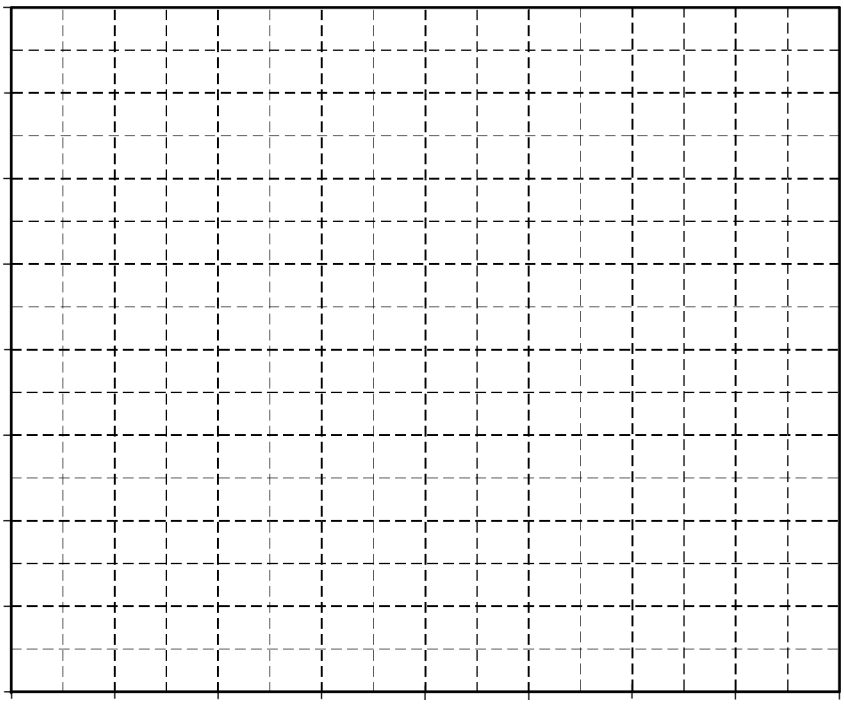
(c) The students want to produce a linear graph of the data so that the capacitance C_U of the unknown capacitor can be determined from the slope of the best-fit line for the data.

i. Indicate two quantities that could be plotted to produce the desired graph. Use the empty columns of the data table in part (b) to record any values that you need to calculate.

Vertical axis _____ Horizontal axis _____

ii. Label the axes below and provide an appropriate scale with units. Plot the data points for the quantities indicated in part (c)(i) on the axes and draw a best-fit line.



iii. Using your best-fit line, determine the capacitance of capacitor C_U.

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Question 2: Experimental Design — 12 points

(a) For a correct ranking — **1 point**

__1__ ΔV_A __1__ ΔV_B __3__ ΔV_C __2__ ΔV_D

For indicating that the resistors in parallel will have the same potential difference — **1 point**

For a justification that indicates $\Delta V_D > \Delta V_C$ because $R_D = 2R_C$ — **1 point**

Total for part (a) — **3 points**

(b)(i) For calculating the correct value of the charge on the $200\,\mu F$ capacitor, including units — **1 point**

Example Response

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

$$Q = C\Delta V = (200\,\mu F)(0.91\,V)$$

$$Q = 1.82 \times 10^{-4}\ C$$

(b)(ii) For indicating one of the following as evidence that the capacitors are in series: — **1 point**

- the potential differences across the capacitors are different
- the sum of the potential differences across the capacitors is constant
- the sum of the potential differences across the capacitors is approximately equal to the potential difference across the battery

(b)(iii) For an explanation that correctly addresses one of the following: — **1 point**

- that the potential differences across the known and unknown capacitor will always be the same
- that the charge on the unknown capacitor cannot be determined

Example Response

Both charge and potential difference across the capacitor are needed to determine C. Arranging the capacitors in parallel will mean both capacitors will have the same potential difference. However, capacitors in parallel will have differing amounts of charge, making it impossible to determine the charge, and, therefore, the capacitance of the unknown capacitor.

Total for part (b) — **3 points**

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(c)(iii)	For using points on the best-fit line to calculate the slope of the line	**1 point**
	For correctly determining the capacitance from the slope of the line	**1 point**

Example Response

Capacitance is equal to slope

$$C_U = \frac{212\ \mu C - 190\ \mu C}{4.10\ V - 3.67\ V}$$
$$C_U = 51.2\ \mu F$$

Total for part (c) 6 points

Total for question 2 12 points

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