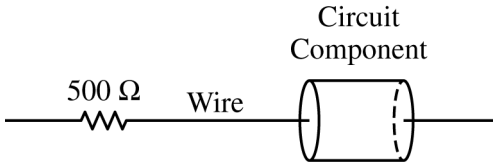
Begin your response to **QUESTION 2** on this page.

2. (12 points, suggested time 25 minutes)

Students are given an unknown circuit component that is connected in series to a resistor with known resistance 500 Ω.

(a) The students are asked to experimentally determine whether the component is a resistor or an uncharged capacitor.

i. Complete the following diagram to show how to use standard circuit equipment to determine whether the component is a resistor or an uncharged capacitor.

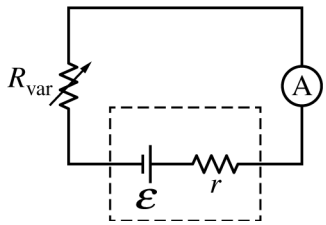


ii. Describe an experimental procedure to determine whether the component is a resistor or an uncharged capacitor. Refer to the circuit equipment in the diagram drawn in part (a)(i).

iii. What results would the students expect if the component is an uncharged capacitor? Support your answer in terms of potential difference and charge.

GO ON TO THE NEXT PAGE.

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



The students conduct a different experiment to determine the emf $\mathcal{E}$ of a battery that is not ideal and has internal resistance $r = 30\,\Omega$. The battery is connected to a variable resistor in a circuit, as shown. The students measure the current I through the circuit for different values of resistance R_{var} of the variable resistor that is connected to the battery. The following table contains the data collected.

I (A)	R_{var} (Ω)		
0.087	200		
0.060	300		
0.042	450		
0.027	700		
0.016	1200		

(b)

i. Write an equation describing the circuit in terms of $\mathcal{E}$, I, r, and R_{var}.

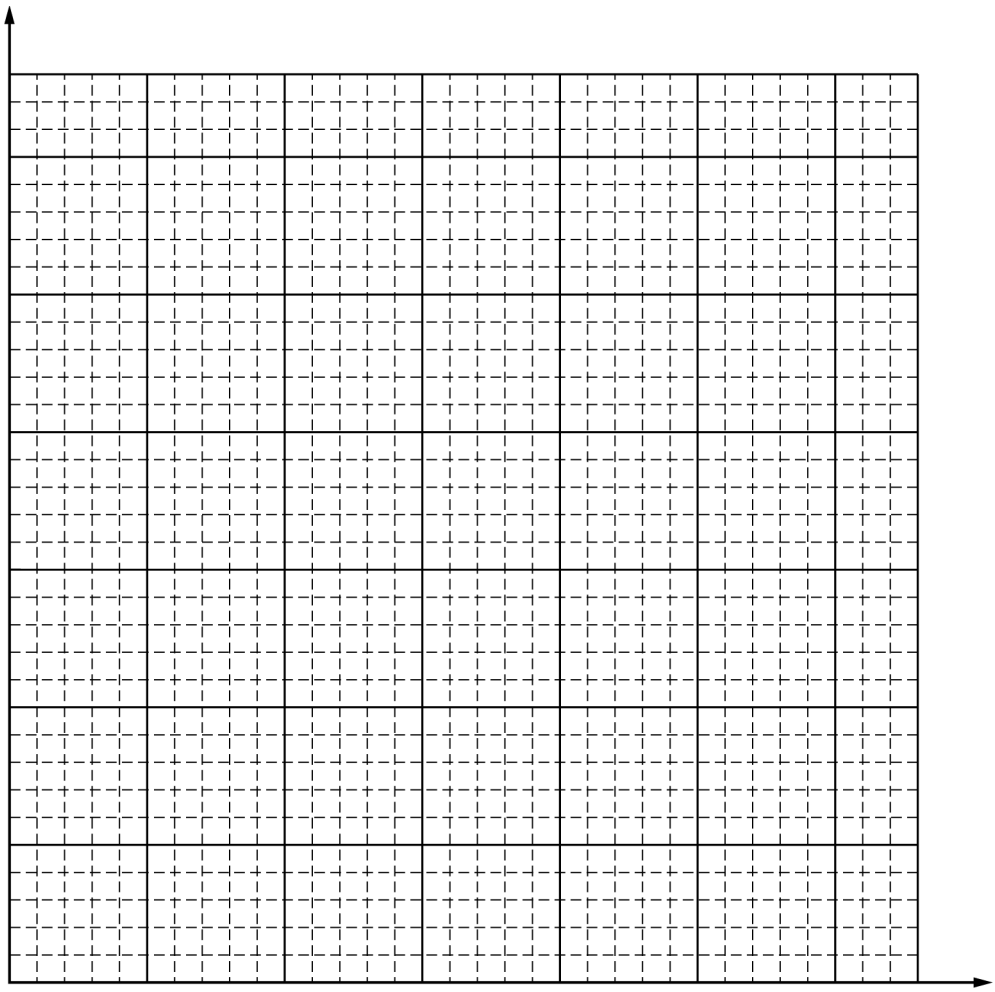
ii. Which quantities could be graphed to yield a straight line that could be used to calculate a numerical value for the emf $\mathcal{E}$ of the battery?

Horizontal Axis:_____ Vertical Axis:_____

GO ON TO THE NEXT PAGE.

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

iii. Plot the data points for the quantities indicated in part (b)(ii) on the following graph. Clearly scale and label all axes, including units. Draw a straight line that best represents the data.
You may use the blank columns in the table for any quantities you graph other than the given data.



iv. Using the graph from part (b)(iii), determine the emf $\mathcal{E}$ of the battery.

GO ON TO THE NEXT PAGE.

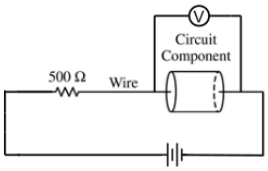
Question 2: Experimental Design — 12 points

(a)(i) For a diagram including a source of potential difference (e.g., battery, power supply) that is in a complete circuit that results in a current in the unknown circuit component — **1 point**

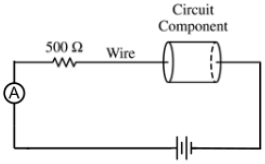
For a diagram including a measurement device that is appropriately connected in the circuit (e.g., voltmeter, ammeter) — **1 point**

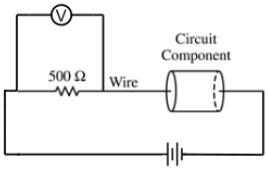
Scoring Note: A lightbulb that is connected in series with the circuit component is an acceptable alternative for an ammeter.

Example Responses

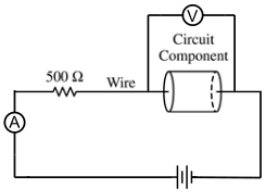


OR

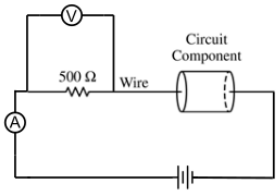




OR



OR



(a)(ii) For describing a procedure that includes a measurement of **one** of the following: — **1 point**

- The potential difference across the circuit component
- The current in the circuit
- The potential difference across the known resistor

For taking measurements at two different times after the circuit is closed or taking one measurement a long time after the circuit is closed, consistent with the procedure described — **1 point**

Example Responses

Measure the current in the ammeter immediately after the circuit is closed and a long time after the circuit is closed.

OR

Measure the potential difference across the circuit component immediately after the circuit is closed and a long time after the circuit is closed.

OR

(b)(iv) For correctly using the graph to determine an experimental value for emf ε, including correct units, between $18.0\ \text{V}$ and $22.0\ \text{V}$ **1 point**

Example Solutions

I as a function of $\dfrac{1}{r + R_{\text{var}}}$

$\varepsilon - Ir - IR_{\text{var}} = 0$

$\varepsilon - I(r + R_{\text{var}}) = 0$

$I(r + R_{\text{var}}) = \varepsilon$

$I = \varepsilon\left(\dfrac{1}{r + R_{\text{var}}}\right)$

$I = \varepsilon\left(\dfrac{1}{30\,\Omega + R_{\text{var}}}\right)$

Slope $= \varepsilon$

$\dfrac{\Delta y}{\Delta x} = \varepsilon$

$\dfrac{(0.08\ \text{A} - 0.04\ \text{A})}{\left(0.004\,\Omega^{-1} - 0.002\,\Omega^{-1}\right)} \approx \varepsilon$

$\varepsilon \approx 20\ \text{V}$

OR

IR_{var} as a function of I

$\varepsilon - Ir - IR_{\text{var}} = 0$

$\varepsilon - Ir = IR_{\text{var}}$

$IR_{\text{var}} = -Ir + \varepsilon$

y-intercept $= \varepsilon$

$\varepsilon \approx 20\ \text{V}$

Total for part (b) 6 points

Total for question 2 12 points