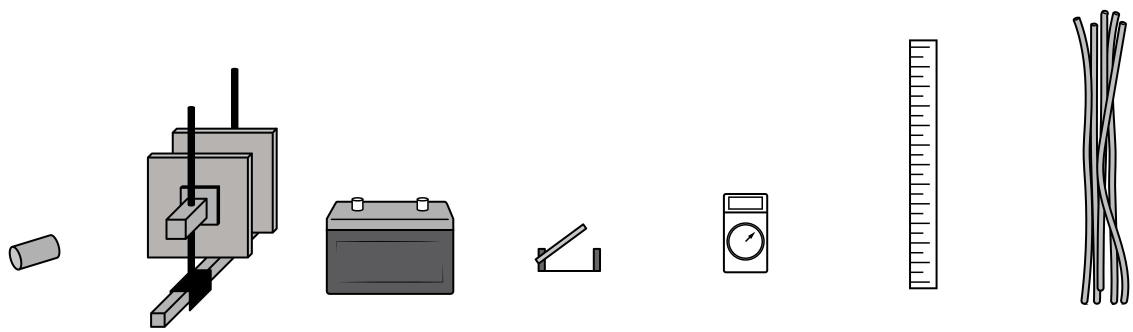
Question 3

3. In Experiment 1, a student is given a resistor of unknown resistance and an air-filled parallel-plate capacitor of unknown capacitance. The student is asked to predict the expected time constant τ of a circuit if these two circuit elements were connected in series with a battery. The student has access to a battery of known emf, a switch, an ammeter, a ruler, and wires, as shown in Figure 1. The plates of the capacitor are square, and the separation between the plates is small compared to the dimensions of the plates. The capacitor is initially uncharged. Assume that the dielectric constant of air is 1.

Figure 1



Resistor Capacitor Battery Switch Ammeter Ruler Wires

Note: Figure not drawn to scale.

A. Describe a procedure for collecting data that would allow the student to determine the expected time constant τ. In your description, include the measurements to be made. Include any steps necessary to reduce experimental uncertainty.

B. Describe how the collected data could be analyzed to determine τ. Include references to appropriate equations and to relationships between measured and known quantities.

C. In Experiment 2, the student is asked to determine the capacitance C of a new parallel-plate capacitor. For each trial, the absolute value $|\Delta V|$ of the potential difference across the capacitor is varied and the charge q stored on one plate of the fully charged capacitor is measured. Table 1 contains the data collected.

Table 1

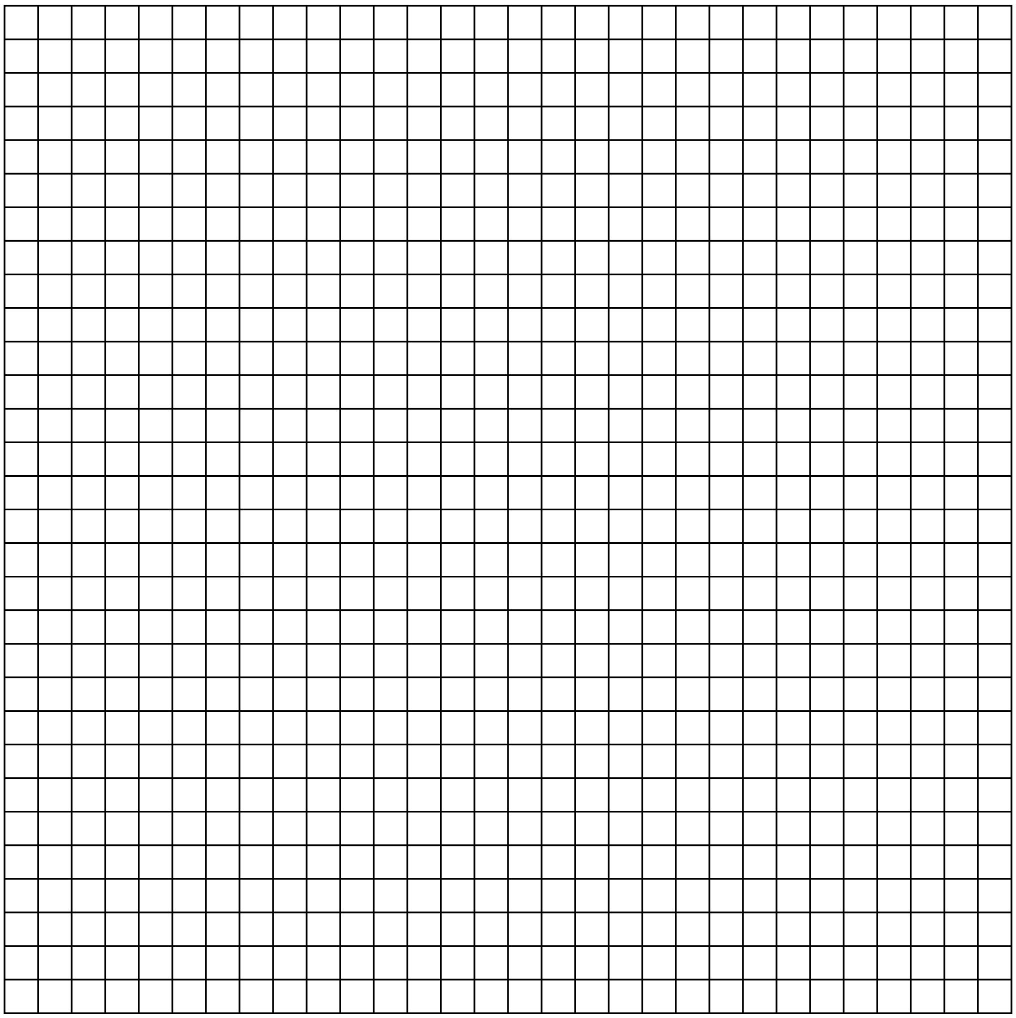
$\lvert\Delta V\rvert$ (V)	$q\ (\times 10^{-10}\ \text{C})$
3.0	2.4
5.0	4.2
7.2	5.6
8.0	6.6
10.0	8.0

i. **Indicate** two quantities, either measured quantities from Table 1 or additional calculated quantities, that could be graphed to produce a straight line that could be used to determine C.

Vertical axis: ______ Horizontal axis: ______

ii. On the grid provided, create a graph of the quantities indicated in part C (i).

- Use Table 2 to record the measured or calculated quantities that you will plot.
- Clearly **label** the axes, including units as appropriate.
- **Plot** the points you recorded in Table 2.



iii. **Draw** a best-fit line for the data graphed in part C (ii).

D. Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for capacitance C.

Question 3: Experimental Design and Analysis (LAB) — 10 points

A

For a procedure that includes **both** of the following measurements: — **Point A1**

- The dimensions of the capacitor
- A current

For a procedure that indicates an appropriate method of reducing experimental uncertainty (e.g., Repeat the procedure multiple times.) — **Point A2**

Example Responses

Measure the length of one side of a capacitor plate. Measure the separation distance between the plates. Construct a circuit that includes the battery and the resistor. Measure the current in the resistor. Repeat measurements of current in the resistor for the described closed circuit.

Measure the length of one side of a capacitor plate. Measure the separation distance between the plates. Construct a circuit that includes the battery, resistor, and capacitor. Measure the initial current in the resistor after the closed circuit is constructed. Disconnect the capacitor from the circuit, discharge the capacitor, and repeat the procedure.

B

For indicating that $\tau = R_{eq}C_{eq}$ can be used to calculate τ — **Point B1**

For **both** of the following: — **Point B2**

- A correct relationship between resistance, the emf of the battery, and current (e.g., $R_{eq} = \frac{\mathcal{E}}{I}$)
- A correct relationship between capacitance, the area of a capacitor plate, and the distance between the capacitor plates (e.g., $C_{eq} = \varepsilon_0 \frac{A}{d}$)

Example Responses

$\tau = R_{eq}C_{eq}$ can be used to determine τ. R_{eq} can be determined by using $R_{eq} = \frac{\mathcal{E}}{I}$, where I is the current in the resistor when the resistor is connected to the battery. C_{eq} can be determined by using $C_{eq} = \varepsilon_0 \frac{A}{d}$, where d is the distance between the capacitor plates and A is the square of the length of a capacitor plate.

$\tau = R_{eq}C_{eq}$ can be used to determine τ. R_{eq} can be determined by using $R_{eq} = \frac{\mathcal{E}}{I}$, where I is the initial current in the resistor when the resistor is connected in series with the battery and the capacitor. C_{eq} can be determined by using $C_{eq} = \varepsilon_0 \frac{A}{d}$, where d is the distance between the capacitor plates and A is the square of the length of a capacitor plate.