

4. (10 points, suggested time 20 minutes)

Some students are investigating the behavior of a circuit with four components in series: a resistor of resistance R , a capacitor of capacitance C , a battery with potential difference $\mathcal{E}$, and a switch. Initially, the capacitor is uncharged and the switch is open.

- (a)
- i. Determine the current in the resistor and the potential difference across the capacitor immediately after the switch is closed.
 - ii. Determine the current in the resistor and the potential difference across the capacitor a long time after the switch is closed.
- (b) The switch is opened, the capacitor is discharged, and a second, identical capacitor is added to the circuit in series with the other components. The switch is then closed again.
- i. A long time after the switch is closed, the energy stored in the single capacitor in the original circuit is U_1 , and the total energy stored in the two capacitors in the new circuit is U_2 . Calculate the ratio U_1/U_2 .
 - ii. The two capacitors in series are to be replaced with a single capacitor that will have the same energy U_2 . Indicate a plate area and a distance between the plates for the new capacitor, compared with one of the original capacitors, that will accomplish this. Support your reasoning using appropriate physics principles and/or mathematical models.

The students are then asked to design two circuits each containing a switch, a battery with a small internal resistance, a lightbulb, and a capacitor. In arrangement 1, the bulb should gradually light up after the switch is closed, becoming brightest after the switch has been closed a long time. In arrangement 2, the bulb should be brightest when the switch is first closed, getting dimmer with time, and going out completely when the switch has been closed for a long time.

- (c) Using standard symbols, draw two circuit diagrams, one showing a possible circuit for arrangement 1 and the other showing a possible circuit for arrangement 2. Justify your circuit diagrams with a paragraph-length explanation referring to the properties of lightbulbs and capacitors in circuits and the conservation of energy and/or the conservation of charge.

STOP

END OF EXAM