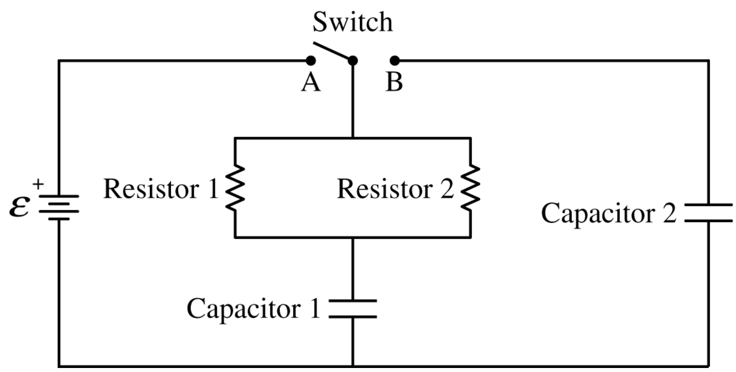
Begin your response to **QUESTION 3** on this page.



3. The circuit shown consists of a battery of emf $\mathcal{E}$, resistors 1 and 2 each with resistance R, capacitors 1 and 2 with capacitances C and $2C$, respectively, and a switch. The switch is initially open and both capacitors are uncharged.

At time $t = 0$, the switch is closed to Position A.

(a) Write, but do NOT solve, a differential equation that can be used to determine the charge Q on the positive plate of Capacitor 1 as a function of time t after the switch is closed to Position A. Express your answer in terms of $\mathcal{E}$, R, C, Q, t, and fundamental constants, as appropriate.

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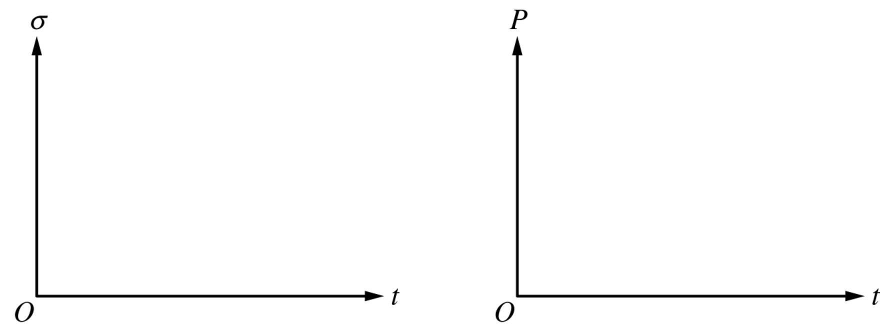
Continue your response to **QUESTION 3** on this page.

(b) On the axes shown, sketch graphs of the surface charge density σ on the positive plate of Capacitor 1 and the total power P dissipated by the resistors as functions of time t from time $t = 0$ until steady-state conditions are nearly reached.



A long time after the switch is closed to Position A, the charge on the positive plate of Capacitor 1 is Q_0 and Capacitor 2 is uncharged.

(c) At time t_1, the switch is closed to Position B.

i. Immediately after time t_1, is the direction of the current in the switch directed toward the left, directed toward the right, or is there no current? Briefly justify your answer.

ii. Determine an expression for the total charge on the positive plate of Capacitor 2 a long time after t_1. Express your answer in terms of Q_0 and fundamental constants, as appropriate.

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Continue your response to **QUESTION 3** on this page.

iii. Derive an expression for the total energy E_R dissipated by resistors 1 and 2 from immediately after time t_1 until new steady-state conditions have been reached. Express your answer in terms of C, Q_0, and fundamental constants, as appropriate.

With the switch still closed to Position B, the parallel plates of Capacitor 2 are moved so that the separation distance increases by a factor of 2.

(d) Determine the ratio $\dfrac{U_2}{U_1}$ of the energy U_2 stored in Capacitor 2 to the energy U_1 stored in Capacitor 1 a long time after the plates of Capacitor 2 have been moved. Briefly justify your answer.

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Continue your response to **QUESTION 3** on this page.

With the capacitors still charged as in part (d), the switch is now closed to Position A.

(e) Express your answers to part (e)(i) and part (e)(ii) in terms of R, C, Q_0, and fundamental constants, as appropriate.

i. Derive an expression for the current I_0 from the battery immediately after the switch is closed to Position A.

ii. Determine the current I_∞ from the battery a long time after the switch is closed to Position A.

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(e)(i)	For a loop rule that includes the terms for the emf of the battery, the potential difference across the pair of resistors, and the potential difference across Capacitor 1	**1 point**

Example Response

$$\mathcal{E} - \Delta V_R - \Delta V_C = 0$$

For a correct answer	**1 point**

Example Response

$$I = \frac{Q_0}{RC}$$

Example Solution

$$\mathcal{E} - \Delta V_R - \Delta V_C = 0$$

$$\mathcal{E} - I\left(\frac{R}{2}\right) - \left(\frac{Q_0}{2C}\right) = 0$$

$$\frac{Q_0}{C} - I\left(\frac{R}{2}\right) - \left(\frac{Q_0}{2C}\right) = 0$$

$$\frac{Q_0}{2C} - I\left(\frac{R}{2}\right) = 0$$

$$\frac{Q_0}{2C} = I\left(\frac{R}{2}\right)$$

$$\frac{Q_0}{C} = IR$$

$$I = \frac{Q_0}{RC}$$

(e)(ii)	For indicating that the current is zero	**1 point**
	Total for part (e)	**3 points**
	Total for question 3	**15 points**