AP® Physics C: Electricity & Magnetism
2002 Sample Student Responses

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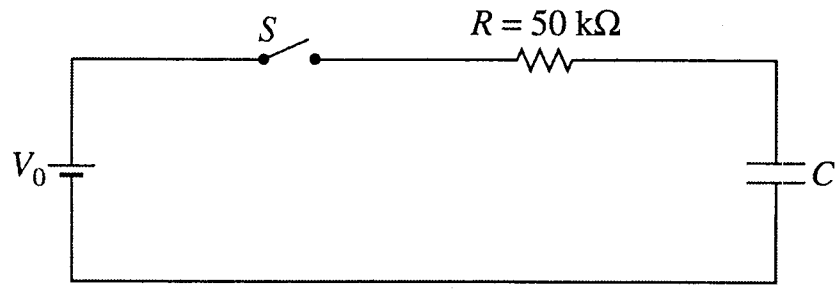

E&M 2.

Your engineering firm has built the RC circuit shown above. The current is measured for the time t after the switch is closed at $t = 0$ and the best-fit curve is represented by the equation $I(t) = 5.20\, e^{-t/10}$, where I is in milliamperes and t is in seconds.

(a) Determine the value of the charging voltage V_0 predicted by the equation.

V_0 is maximal at time $t=0$, so this is

$V_0 = R\,I(0) = 50\text{k}\Omega \cdot 5.20\text{mA} =$ **260 V.**

(b) Determine the value of the capacitance C predicted by the equation.

The time constant is $RC = 10$ for an RC circuit, so

$C = \frac{10}{R} =$ **200 μF.**

(c) The charging voltage is measured in the laboratory and found to be greater than predicted in part (a).

i. Give one possible explanation for this finding.

$I(t) = 5.20e^{-t/10}$ is a best fit curve, which doesn't necessarily contain the pt. V_0. In fact, with an internal resistance in the battery RC increases, which decreases $I(t)$. This gives a best-fit curve which compensates for this, making V_0 larger.

ii. Explain the implications that your answer to part i has for the predicted value of the capacitance.

$Q = \frac{Q}{V_0}$ in the circuit, so a larger V_0 would make the predicted value C smaller, since Q is constant @ full capacitance.

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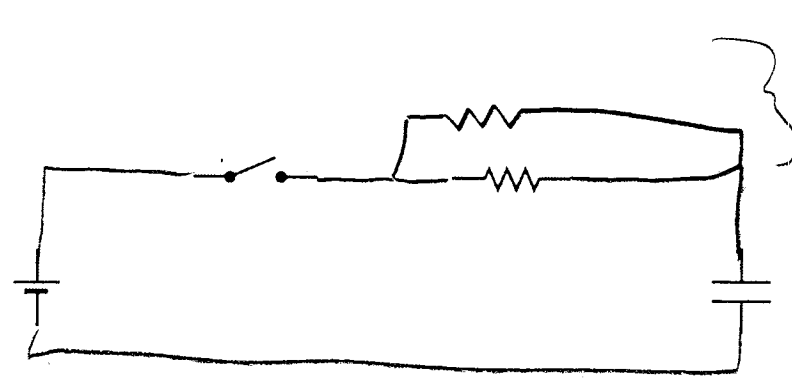
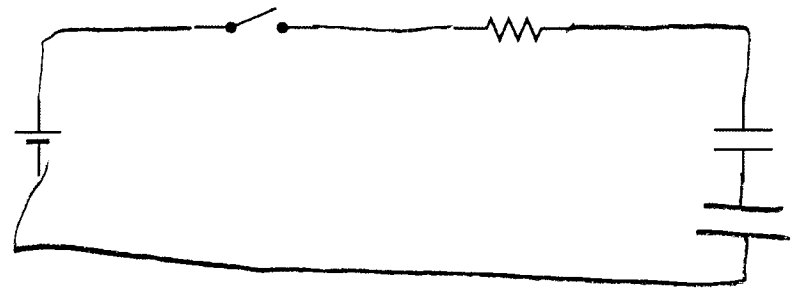
(d) Your laboratory supervisor tells that you the charging time must be decreased. You may add resistors or capacitors to the original components and reconnect the *RC* circuit. In parts i and ii below, show how to reconnect the circuit, using either an additional resistor or a capacitor to decrease the charging time.

i. Indicate how a resistor may be added to decrease the charging time. Add the necessary resistor and connections to the following diagram.



ii. Instead of a resistor, use a capacitor. Indicate how the capacitor may be added to decrease the charging time. Add the necessary capacitor and connections to the following diagram.



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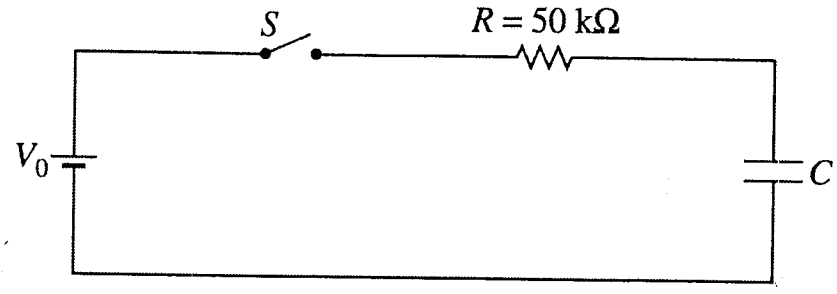

E&M 2.

Your engineering firm has built the RC circuit shown above. The current is measured for the time t after the switch is closed at $t = 0$ and the best-fit curve is represented by the equation $I(t) = 5.20\, e^{-t/10}$, where I is in milliamperes and t is in seconds.

(a) Determine the value of the charging voltage V_0 predicted by the equation.

$I_{max} = I(0) = 5.20$ milliamperes $= 5.20 \times 10^{-3}$ A

$V_0 = IR = (5.20 \times 10^{-3})(50\ k\Omega)\left(\frac{1000\ \Omega}{1\ k\Omega}\right) = 260$ Volts

(b) Determine the value of the capacitance C predicted by the equation.

(c) The charging voltage is measured in the laboratory and found to be greater than predicted in part (a).

i. Give one possible explanation for this finding.

the equation for $I(t)$ is derived from a best-fit curve which means it is an approximation of the actual equation for $I(t)$. Because V_0 has greater than expected, the estimated $I(t)$ is too low.

ii. Explain the implications that your answer to part i has for the predicted value of the capacitance.

If the charge stored in the capacitor is the same, then a higher V_0 will result in a lower C.

$Q = CV_0 \qquad C = \frac{Q}{V_0}$

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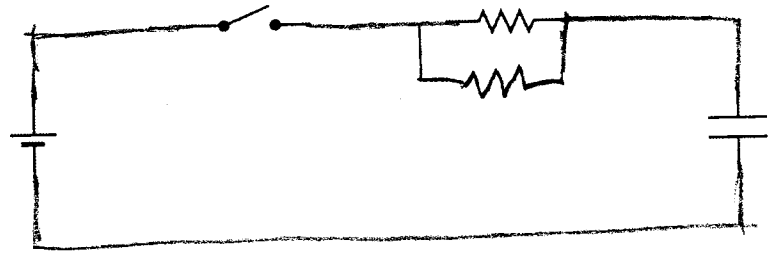
(d) Your laboratory supervisor tells that you the charging time must be decreased. You may add resistors or capacitors to the original components and reconnect the *RC* circuit. In parts i and ii below, show how to reconnect the circuit, using either an additional resistor or a capacitor to decrease the charging time.

i. Indicate how a resistor may be added to decrease the charging time. Add the necessary resistor and connections to the following diagram.

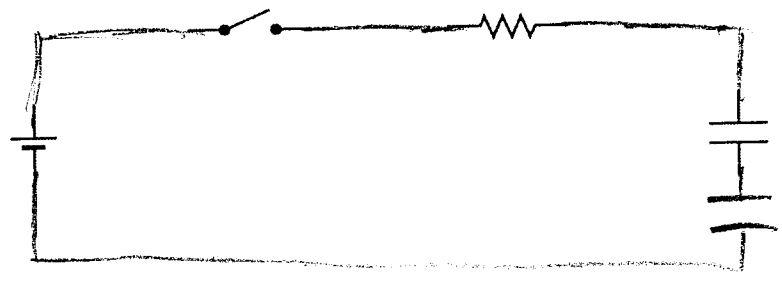


With resistors in parallel,

$$\frac{1}{R_{EQ}} = \frac{1}{R_1} + \frac{1}{R_2}$$

So adding another resistor will lower the overall resistance, and the time constant, RC, will be lowered.

ii. Instead of a resistor, use a capacitor. Indicate how the capacitor may be added to decrease the charging time. Add the necessary capacitor and connections to the following diagram.



With capacitors in series,

$$\frac{1}{C_{EQ}} = \frac{1}{C_1} + \frac{1}{C_2}$$

So adding another capacitor will lower the overall capacitance, and the time constant, RC, is lowered.

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