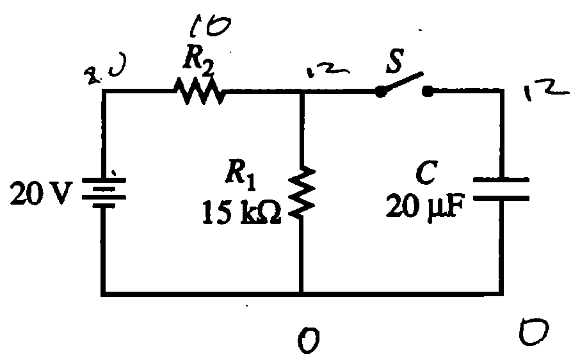
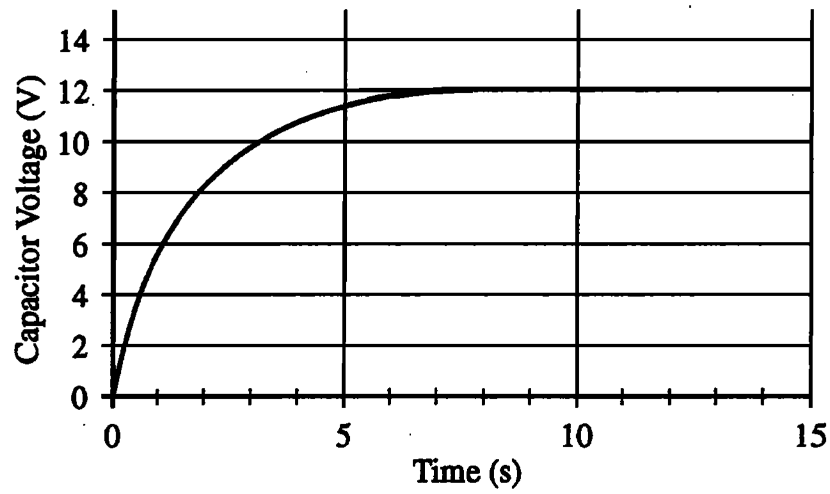
AP® Physics C: Electricity and Magnetism
2004 Sample Student Responses





E&M. 2.

In the circuit shown above left, the switch S is initially in the open position and the capacitor C is initially uncharged. A voltage probe and a computer (not shown) are used to measure the potential difference across the capacitor as a function of time after the switch is closed. The graph produced by the computer is shown above right. The battery has an emf of 20 V and negligible internal resistance. Resistor R_1 has a resistance of 15 kΩ and the capacitor C has a capacitance of 20 μF.

(a) Determine the voltage across resistor R_2 immediately after the switch is closed.

20 V, since no current will go through R_1

(b) Determine the voltage across resistor R_2 a long time after the switch is closed.

20 − 12 = 8 V, since voltage across C is 12 V, and voltage across R_1 is 12 V

V = IR

(c) Calculate the value of the resistor R_2.

$$\frac{8}{20} = \frac{R_2}{15 + R_2}$$

$$8(R_2 + 15) = 20R_2$$

$$8R_2 + 120 = 20R_2$$

$$12R_2 = 120$$

$$R_2 = 10\ \text{k}\Omega$$

(d) Calculate the energy stored in the capacitor a long time after the switch is closed.

$$E = \frac{1}{2}CV^2$$

$$= \frac{1}{2}(20\,\mu F)(12\,V)^2$$

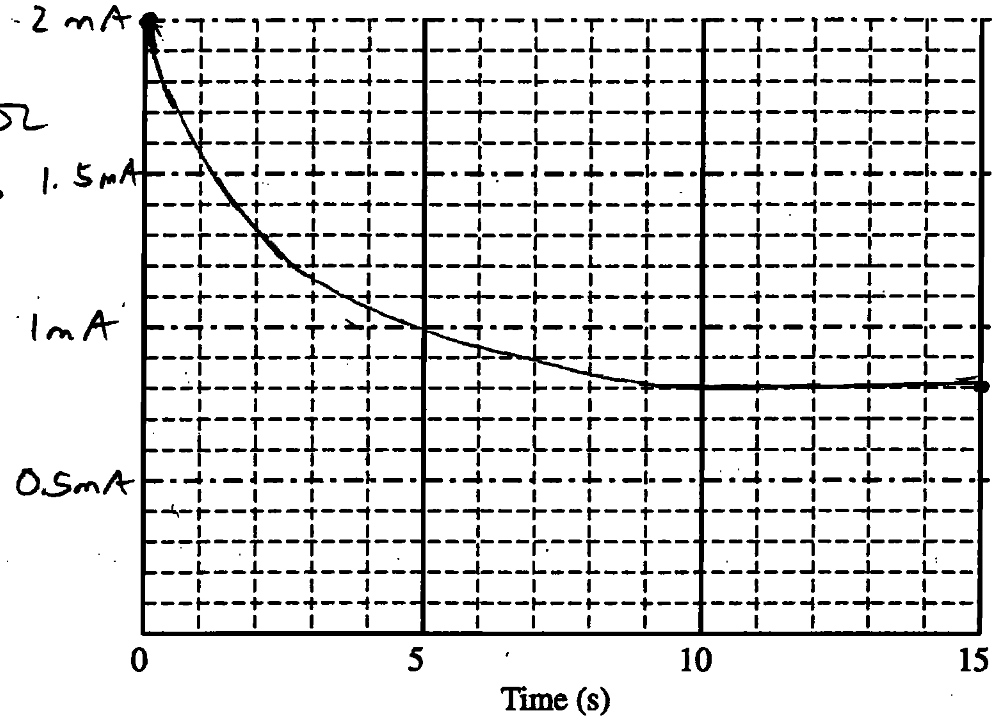
$$= \frac{1}{2}(20 \times 10^{-6})(144)$$

$$= 1.44 \times 10^{-3}\ J$$

A2

E E E E E E E E E E

(e) On the axes below, graph the current in R_2 as a function of time from 0 to 15 s. Label the vertical axis with appropriate values.



$I_f = \frac{V_f}{R_T} = \frac{20}{25k\Omega}$

$= 0.8 \times 10^{-3}$

@ $t = \infty$

$I = 0.8 mA$

$V_0 = I_0 R$

$20 = I_0(10 \times 10^3)$

$I_0 = 2 \times 10^{-3}$

$= 2 mA$

Resistor R_2 is removed and replaced with another resistor of lesser resistance. Switch S remains closed for a long time.

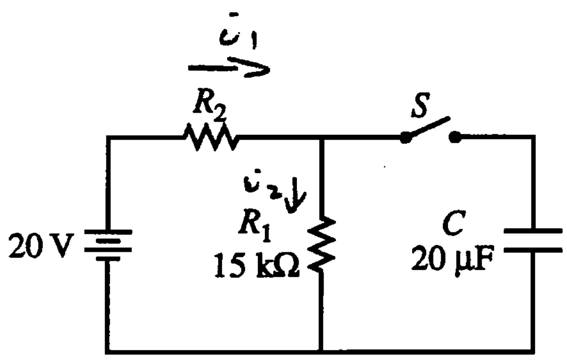
(f) Indicate below whether the energy stored in the capacitor is greater than, less than, or the same as it was with resistor R_2 in the circuit.

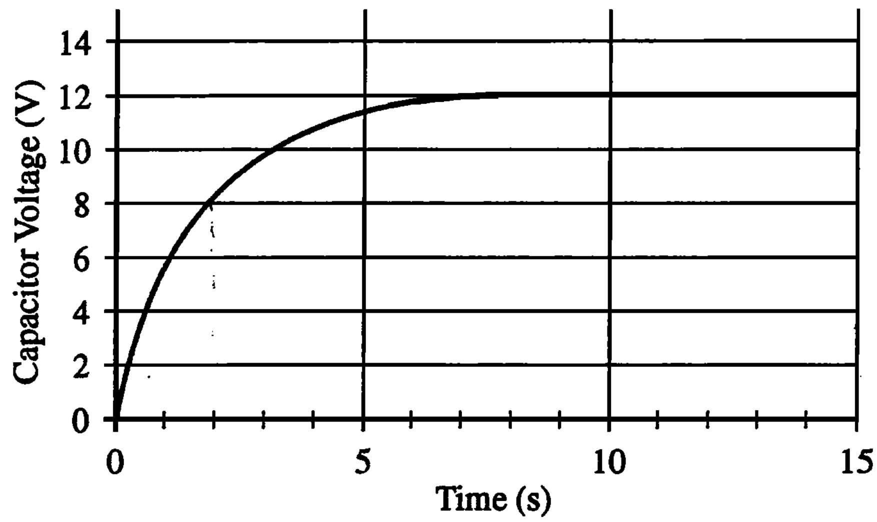
✓ Greater than ____ Less than ____ The same as

Explain your reasoning.

If R_2 is replaced with a resistor of smaller resistance, the voltage drop across the new resistor will be smaller and thus the voltage drop across the capacitor will be greater, leading to a larger stored energy, since $E = \frac{1}{2}CV^2$

GO ON TO THE NEXT PAGE.





E&M. 2.

In the circuit shown above left, the switch S is initially in the open position and the capacitor C is initially uncharged. A voltage probe and a computer (not shown) are used to measure the potential difference across the capacitor as a function of time after the switch is closed. The graph produced by the computer is shown above right. The battery has an emf of 20 V and negligible internal resistance. Resistor R_1 has a resistance of 15 kΩ and the capacitor C has a capacitance of 20 μF.

(a) Determine the voltage across resistor R_2 immediately after the switch is closed.

Immediately after the switch is closed, the capacitor acts as a wire, so $V_{R_2} = \mathcal{E} = 20\,[V]$

(b) Determine the voltage across resistor R_2 a long time after the switch is closed.

A long time afterwards,

$V_{R_2} + V_c = \mathcal{E} \Rightarrow V_{R_2} = \mathcal{E} - V_c = 20\,[V] - 12\,[V] = 8\,[V]$

(c) Calculate the value of the resistor R_2.

$V_{R_1} = V_c$ by the loop rule.

So, $V_{R_1} = i_2 R_1$

$\Rightarrow i_2 = \frac{V_{R_1}}{R_1} = \frac{V_c}{R_1} = \frac{12\,[V]}{15\,[k\Omega]} = 8.0\times10^{-4}\,[A]$

$i_1 = i_2 = 8.0\times10^{-4}\,[A]$

$R_2 = \frac{V_{R_2}}{i_1} = \frac{8\,[V]}{8.0\times10^{-4}\,[A]} = 10.\,[k\Omega]$

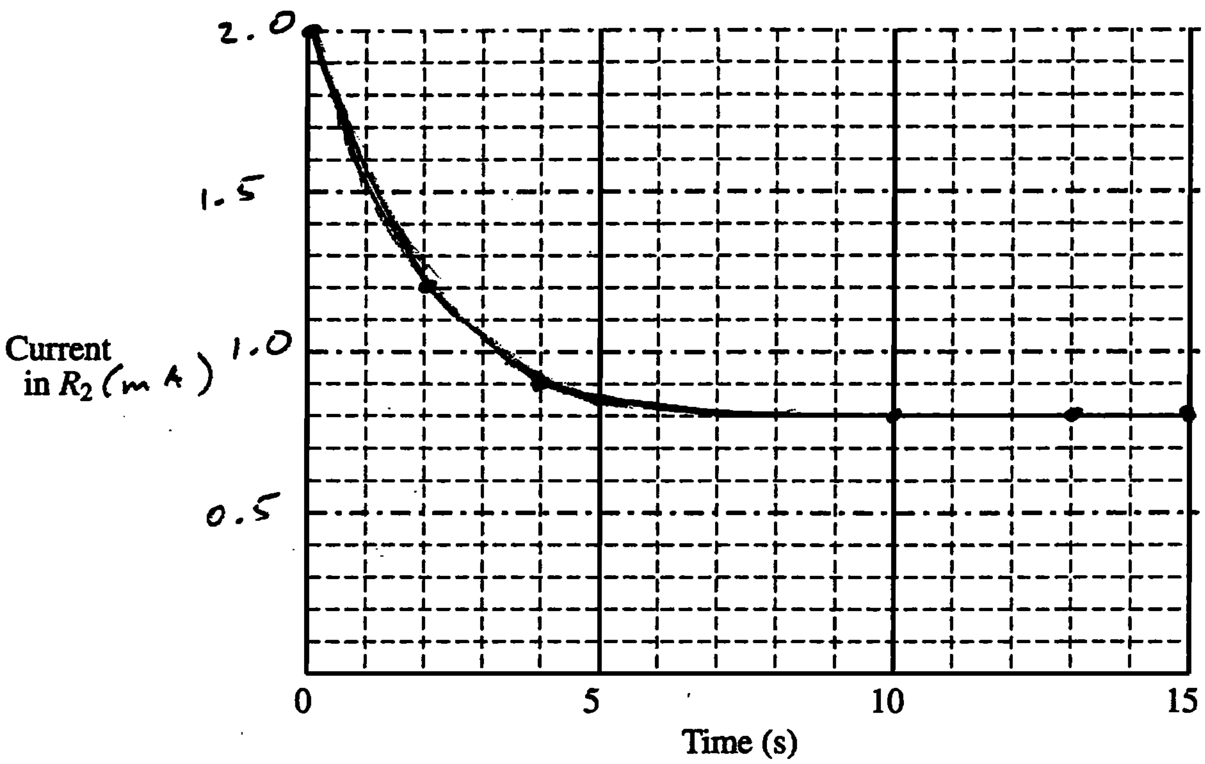
(d) Calculate the energy stored in the capacitor a long time after the switch is closed.

$E = \frac{1}{2}CV^2 = \frac{1}{2}\cdot 20\times10^{-6}\,[F]\,(12\,[V])^2$

$= 1.44\times10^{-3}\,[J]$

GO ON TO THE NEXT PAGE.

(e) On the axes below, graph the current in R_2 as a function of time from 0 to 15 s. Label the vertical axis with appropriate values.



$iR_2 + V = \mathcal{E}$

$i = \dfrac{\mathcal{E} - V}{R_2}$

Resistor R_2 is removed and replaced with another resistor of lesser resistance. Switch S remains closed for a long time.

(f) Indicate below whether the energy stored in the capacitor is greater than, less than, or the same as it was with resistor R_2 in the circuit.

____ Greater than ____ Less than __X__ The same as

Explain your reasoning.

The energy stored by a capacitor is determined by its capacitance and the amount of charge it can hold. These do not change when R_2 changes, so the energy stored is the same.

(since $E = \frac{Q^2}{2C}$)