AP Physics - Electricity - RC Circuits

Note Title 3/20/2008

Up until now, we have been concerned only with the steady state values of current, voltage, and power in different circuit elements. Certain circuit elements, like capacitors, actually exhibit behavior that change over time. This is called transient behavior.

Capacitor	Behavior
Uncharged	• Charge is free to accumulate with no resistance. • Capacitor behaves like a conducting wire.
Charged	• No more charge can accumulate (capacitor is "full") • Capacitor behaves like an open circuit → No current flows through it.

So, as we charge up a capacitor, current through it will gradually drop to zero.

If a problem states that a circuit has acheived "steady state," this is synonymous with saying that a very long time has elapsed.

Simple Resistor-Capacitor (RC) Circuit

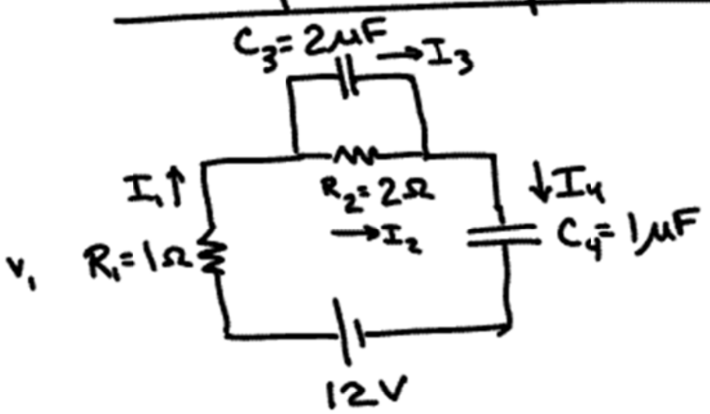
Initial state: Capacitor uncharged
Battery is disconnected

@ $t=0^+$ – Battery is connected
- All current flows through capacitor
→ No current thru resistor $I_R=0$

t from 0^+ to steady state:
- Capacitor charges up → R_c increases
→ Current increases through resistor, decreases through capacitor

$t=\infty$ (steady state):
- Capacitor is fully charged
→ $I_C=0$
- $V_R=V_B$
- $I_R=\frac{V_B}{R}$

Example: Compound RC Circuit



Initial Condition: Capacitors Uncharged
Battery disconnected

@ $t=0$ - Battery Connected
All current goes through C_3 and C_4
$V_1=12V$ $V_4=0V$

$I_1=\frac{12V}{1\Omega}=12A$ $I_3=12A$
$I_2=0A$ $I_4=12A$

As time increases
C_3 and C_4 begin charging
→ I_3 and I_4 decrease
→ I_2 increases initially

As $t \to \infty$, steady state is acheived

Capacitor 4 is completely charged

$\rightarrow I_4 = 0 \rightarrow I_1 = 0$

$\rightarrow V_1 = I_1 R_1 = 0 \rightarrow$ No voltage across resistor 1

$V_3 = 0$ because remaing charge on C_3 bleeds away through R_2 to other side of C_3

$\rightarrow I_3 = 0$

$\rightarrow$ Capacitor 3 is uncharged

Total charge of capacitor 4 in Steady State

$$Q_4 = C_4 V_4$$

$$Q = (1\mu F)(12V) = (1 \cdot 10^{-6} F)(12V)$$

$$Q = 1.2 \cdot 10^{-5} \text{ coulombs}$$

Energy in Capacitor 4 in Steady State

$$U = \frac{1}{2} C V^2$$

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

$$U = 72 J$$