EECS2200 Electric Circuits

Chapter 5 Part 1

Activities

Activity 1

Look at the capacitor equation:

$$i(t) = C\frac{dv(t)}{dt}$$

Suppose *v(t)* is constant, what is the value of *i(t)*?

A. 0

B. ∞

C. a constant

Activity 2

if the voltage drop across the capacitor is constant, its current is 0, so the capacitor can be replaced by:

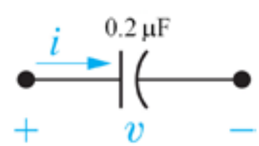
A. A short circuit

B. An open circuit

C. a constant

Activity 3

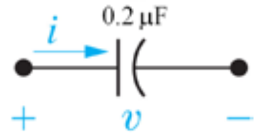
Find the voltage, power, and energy



$$i(t) = \begin{cases} 0, & t \leq 0; \\ 5000t \text{ A}, & 0 \leq t \leq 20\ \mu\text{s}; \\ 0.2 - 5000t \text{ A}, & 20 \leq t \leq 40\ \mu\text{s}; \\ 0, & t \geq 40\ \mu\text{s}. \end{cases}$$

Solution

$$i(t) = \begin{cases} 0, & t \le 0; \\ 5000t\ \text{A}, & 0 \le t \le 20\ \mu\text{s}; \\ 0.2 - 5000t\ \text{A}, & 20 \le t \le 40\ \mu\text{s}; \\ 0, & t \ge 40\ \mu\text{s}. \end{cases}$$



For $t < 0$:

$$v(t) = 0\ \text{V}; \qquad p(t) = 0\ \text{W}; \qquad w(t) = 0\ \text{J}$$

For $0 \le t \le 20\mu\text{s}$:

$$v(t) = \frac{1}{0.2\mu}\int_0^t 5000x\,dx + v(0) = \frac{1}{0.2\mu}\left.\frac{5000x^2}{2}\right|_0^t = 12.5\times10^9 t^2\ \text{V}$$

$$p(t) = v(t)i(t) = (12.5\times10^9 t^2)(5000t) = 62.5\times10^{12} t^3\ \text{W}$$

$$w(t) = \tfrac{1}{2}(0.2\mu)(12.5\times10^9 t^2)^2 = 15.625\times10^{12} t^4\ \text{J}$$

At $t = 20\mu\text{s}$, $\quad v(20\mu\text{s}) = 12.5\times10^9(20\mu)^2 = 5\ \text{V}$

Solution

$$i(t) = \begin{cases} 0, & t \le 0; \\ 5000t\ \text{A}, & 0 \le t \le 20\ \mu\text{s}; \\ 0.2 - 5000t\ \text{A}, & 20 \le t \le 40\ \mu\text{s}; \\ 0, & t \ge 40\ \mu\text{s}. \end{cases}$$

For $20\mu\text{s} \le t \le 40\mu\text{s}$:

$$v(t) = \frac{1}{0.2\mu}\int_{20\mu}^t (0.2 - 5000x)\,dx + v(20\mu)$$

$$= \frac{1}{0.2\mu}\left[0.2x - \frac{5000x^2}{2}\right]\Bigg|_0^t + 5$$

$$= (10^6 t - 12.5\times10^9 t^2 - 10)\ \text{V}$$

$$p(t) = v(t)i(t); \qquad w(t) = \tfrac{1}{2}Cv(t)^2$$

At $t = 40\mu\text{s}$, $\quad v(40\mu\text{s}) = [10^6(40\mu) - 12.5\times10^9(40\mu)^2 - 10) = 10\ \text{V}$

Solution

$$i(t) = \begin{cases} 0, & t \le 0; \\ 5000t \text{ A}, & 0 \le t \le 20\ \mu\text{s}; \\ 0.2 - 5000t \text{ A}, & 20 \le t \le 40\ \mu\text{s}; \\ 0, & t \ge 40\ \mu\text{s}. \end{cases}$$

For $t \ge 40\mu\text{s}$:

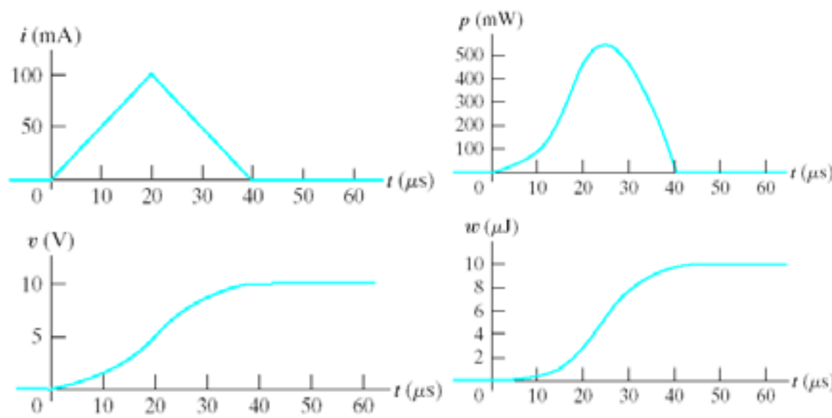
$$v(t) = \frac{1}{0.2\mu}\int_{40\mu}^{t} 0\ dx + v(40\mu) = 10\ \text{V}$$

$$p(t) = v(t)i(t) = 0\ \text{W}$$

$$w(t) = \tfrac{1}{2}(0.2\mu)(10)^2 = 10\mu\text{J}$$

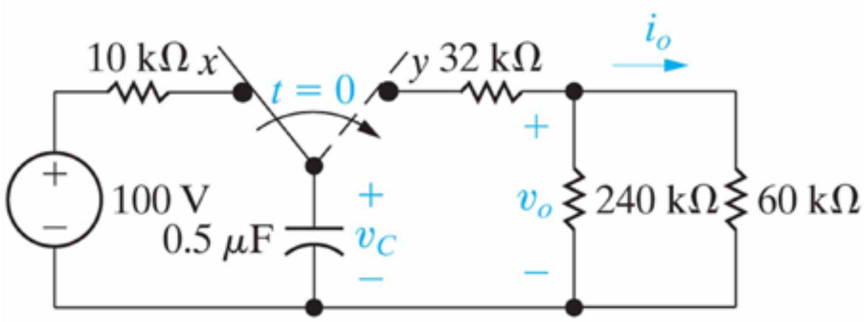
During the interval between 0 and 40μs, the power is positive (absorbed), energy is stored and "trapped" by the capacitor, so even when the current goes to 0, the voltage stays at 10 V and the energy is non-zero.

Solution



Activity 4

Find $V_c(t)$ for t>=0

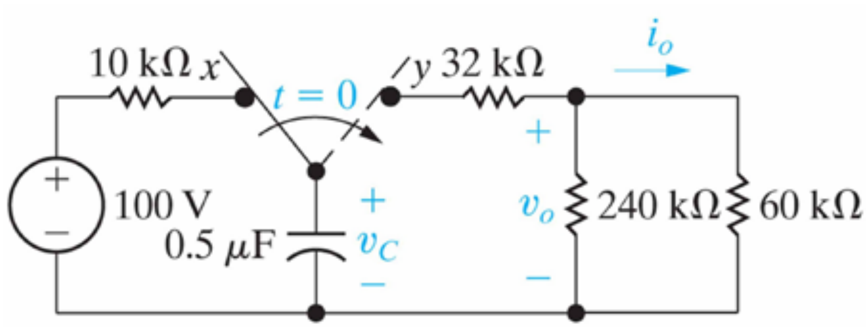


Solution

R_{eq}=32+240//60=80kΩ

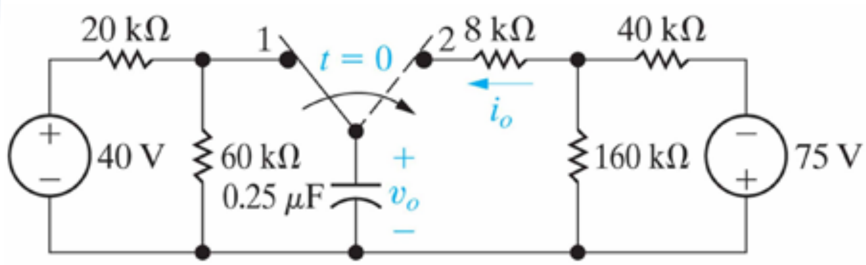
$$v_C(t) = 100e^{-(1/RC)t}, \quad \tau = RC = 80\times10^3 \times 0.5\times10^{-6} = 4ms$$

$$v_C(\text{t}) = 100e^{-25t}V$$



Activity 5

The switch has been in position 1 for a long time. At t=0, the switch moves to position 2. Find $v_0(t)$ for t>=0 and $i_o(t)$ for $t>=0^+$



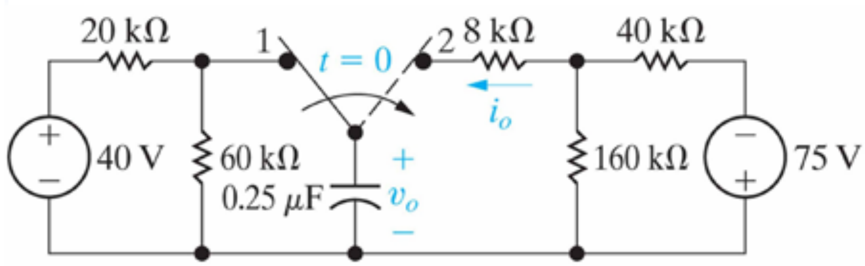
Solution

1. Switch was in position 1 for a long time,

V_0=60/(20+60)*40V=30V (voltage divider)

2. After switch moves to position 2, the open circuit voltage is:

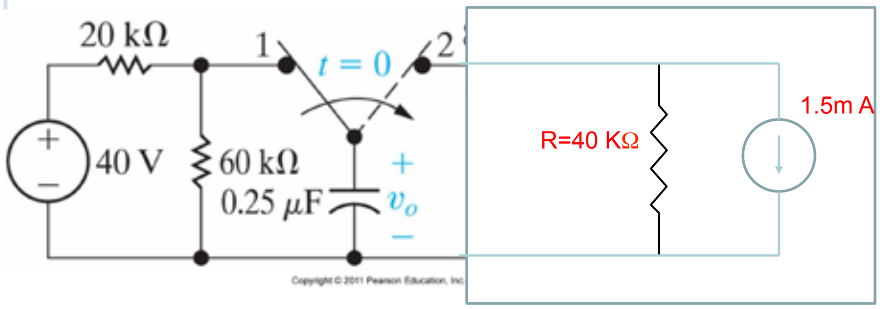
V_{oc}=160/(40+160)*(-75V)=-60V



Solution

3. Replace the right part with a Norton equivalent,

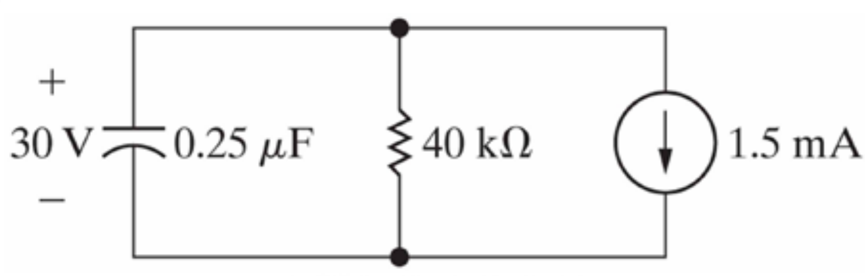
V_{oc}=-60V, R_{TH}=8k+40k//160k=40kΩ



Solution

Since V_o=30V, I_sR=-60V, RC=10ms,

$$v_o(t) = I_s R + (V_0 - I_s R)e^{-t/RC}$$
$$= -60 + [30 - (-60)]e^{-100t}$$
$$= -60 + 90e^{-100t}$$



Solution

Since I_s=-1.5mA, V_0/R=0.75mA,

$$i(t) = \left(I_s - \frac{V_0}{R}\right)e^{-t/RC}$$

$$= (-1.5 - 0.75)e^{-100t}$$

$$= -2.25e^{-100t} mA$$