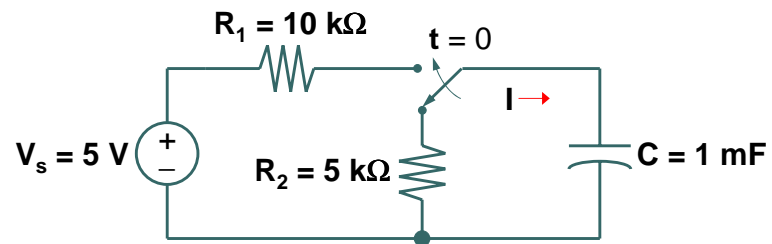
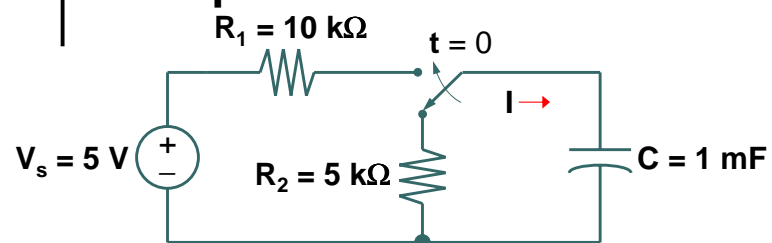


## ● ● ● | Lecture 12: RC Example



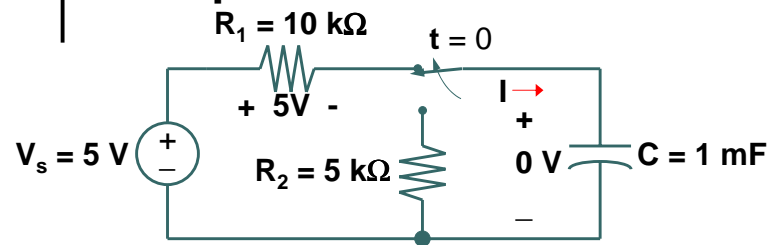
Find the current  $I(t)$ .

## ● ● ● | Example: Initial Condition



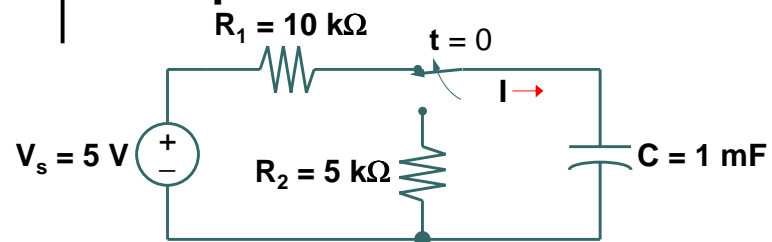
- We first find capacitor voltage right after the switch, (at  $t=0^+$ ) and use it to find the current  $I$  at  $t=0^+$ .
- To do this, we look at the circuit before switching, because the capacitor voltage will remain the same after switching.
- Assuming the circuit has been “unswitched” for a long time, the capacitor acts like an open circuit connected to a resistor.
- The capacitor voltage before switching (at  $t=0^-$ ) is 0 V.
- The capacitor voltage after switching (at  $t=0^+$ ) is 0 V.

## ● ● ● Example: Initial Condition



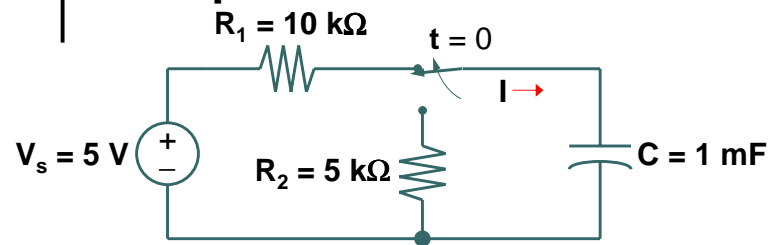
- We know the capacitor voltage is  $0\text{ V}$  right after the switch.
- By KVL, the resistor gets all  $5\text{ V}$  that the source puts out.
- So by Ohm's law,  $I(0^+)$  is  $5\text{ V} / 10\text{ k}\Omega = 0.5\text{ mA}$

## ● ● ● Example: Final Value



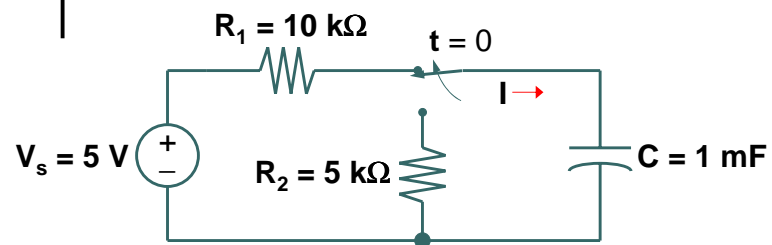
- After the circuit has been switched for a long time, the capacitor will act like an open circuit.
- Then no current can flow—eventually,  $I$  goes to zero.
- $I_f = 0\text{ A}$

## ● ● ● Example: Time Constant



- How long does it take for the current to converge after switching?
- Look at the circuit after switching to find the time constant.
- The  $5\text{ k}\Omega$  resistor is not “in” the circuit after the switch.
- $R = 10\text{ k}\Omega$ ,  $C = 1\text{ mF}$  so  $\tau = 10\text{ s}$

## ● ● ● Example: Final Answer

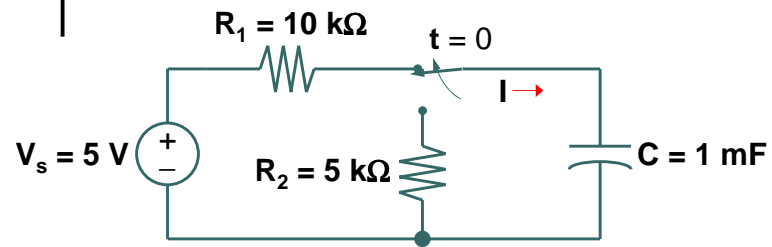


- Plugging in, we get:

$$I(t) = I_f + (I(0^+) - I_f) e^{-t/RC}$$

$$I(t) = 0 + (0.5\text{ mA} - 0) e^{-t/10} = 0.5 e^{-t/10}\text{ mA}$$

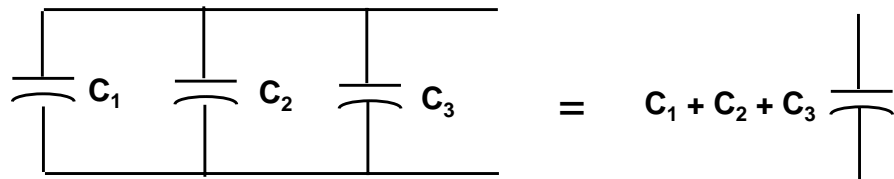
## ● ● ● Example: Alternative Method



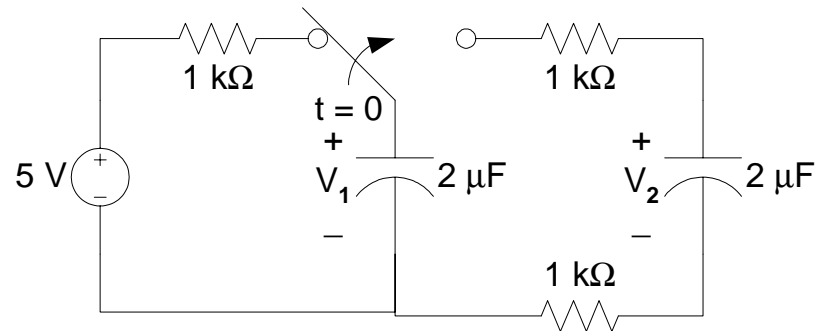
- The initial capacitor voltage was  $V_C(0^+) = 0$  V.
- The time constant is  $\tau = 10$  s.
- The final value of the capacitor voltage, when the capacitor has gone to an open circuit, is  $V_{C,F} = 5$  V.
- Plug in to get  $V_C(t) = 5 - 5 e^{-t/10}$  V.
- Since  $I = C \, dV/dt$ ,  $I(t) = (10^{-3})((-5)/(-10)) e^{-t/10}$  A

## ● ● ● Series and Parallel Capacitors

- Capacitors combine the **opposite** way as compared to resistors.

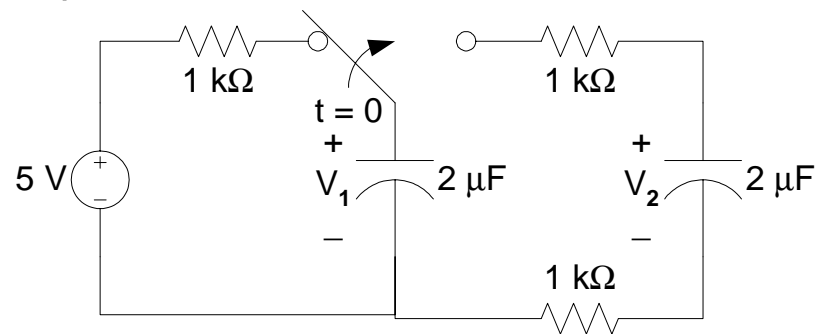


## ● ● ● Hard Example



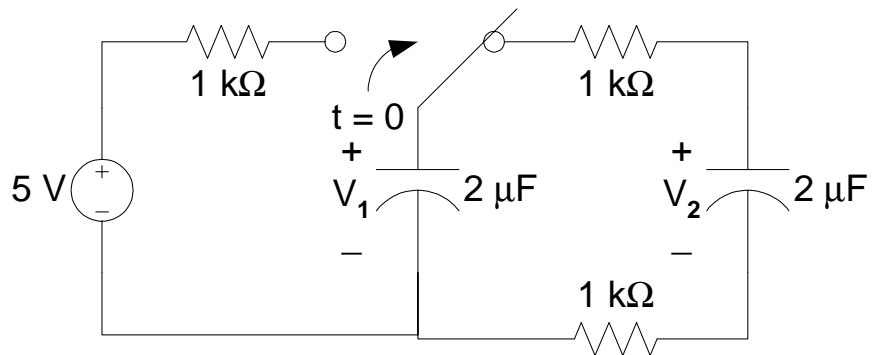
- Find  $V_1(t)$  and  $V_2(t)$ .
- Find the energy absorbed by the resistors for  $t > 0$ .

## ● ● ● Initial Conditions



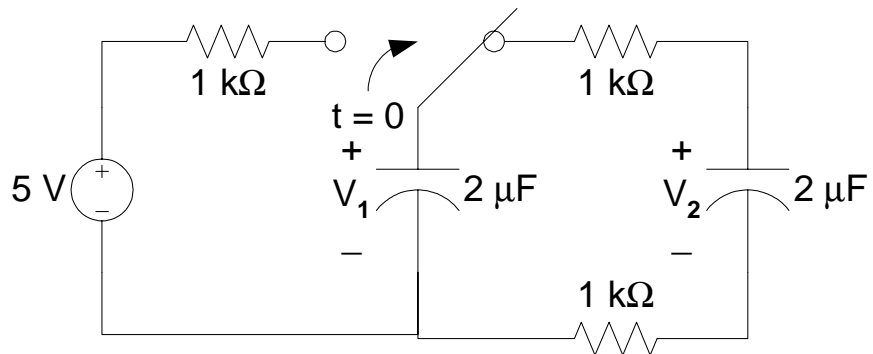
- Consider the circuit before the switch—it had been that way for a long time. Assume second capacitor is discharged at  $t=0$ .

## Time Constant



- How long does it take to converge after switch?
- What are  $R$  and  $C$ ?

## Final Value



- After a while, **both** capacitors are open circuits.
- They can have nonzero voltage, but voltages must be equal.
- Equate  $V = Q/C$  for capacitors to gain insight into final value...



## Solutions

- Energy is time integral of power. Find  $P = VI = R(I^2)$ .



## DRAM

- Dynamic Random Access Memory (DRAM) cells are really just capacitors. Each capacitor is one bit.
- The circuit we just saw simulates the writing and reading of a DRAM cell (capacitor 1).
- A logic gate that needed to use the contents of the DRAM cell would be represented by an RC circuit, and the DRAM capacitor would need to charge the logic gate's natural capacitance.
- DRAM capacitors are connected to electronic switches, not physical switches. So there is always a little current flowing.
- This drains the charge from the DRAM capacitors. They need to be “refreshed” periodically. Hence the term **dynamic**.