RC & RL CIRCUITS

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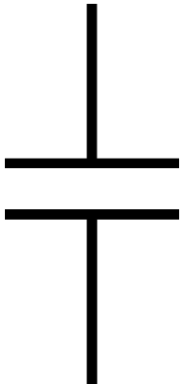
Energy Storage Element

Capacitor



Energy store in form of Electric field and release in form of voltage

$$I = C\frac{dv}{dt}$$

$$v = \frac{1}{C} + \int_{t_0}^{t} I\,dt + v(t_0)$$

In steady state the capacitor will act as an open circuit.

Inductor

Energy store in form of Magnetic field and release in form of current

$$v = L\frac{di}{dt}$$

$$i = \frac{1}{L} + \int_{t_0}^{t} v\,dt + i(t_0)$$

In steady state the inductor will act as an short circuit.

First Order Circuit Complete Response

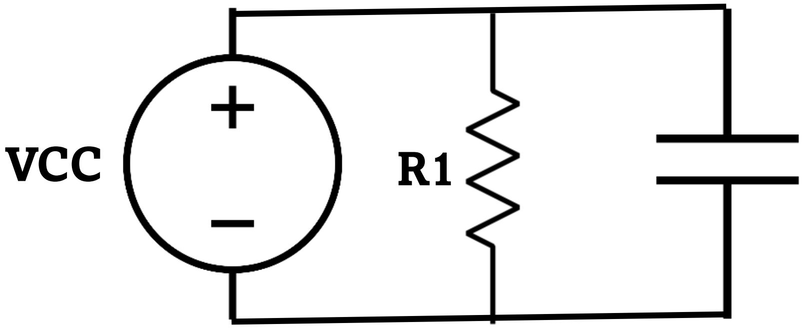
The first order circuit respond can be decompose to the sum of natural respond and forced respond

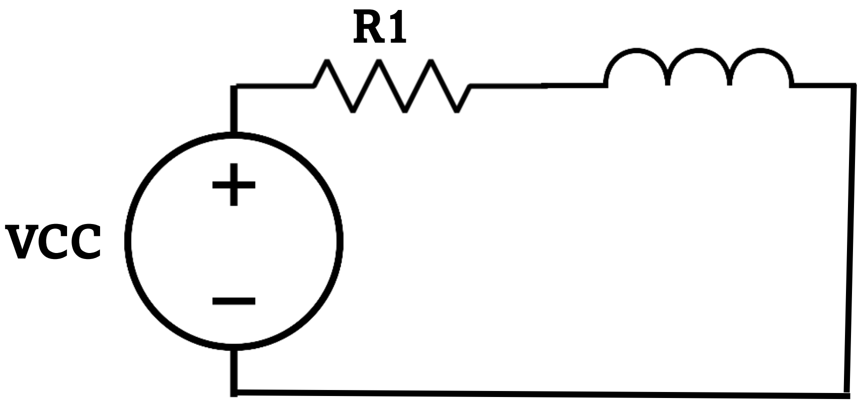
$$v(t) = v_n(t) + v_f(t)$$

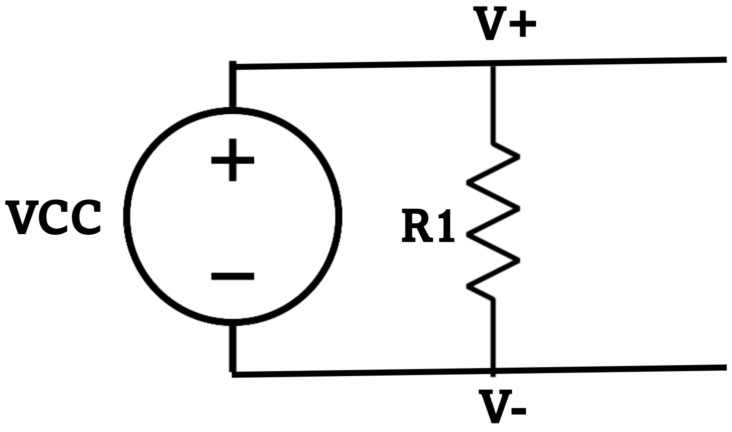
$$i(t) = i_n(t) + i_f(t)$$

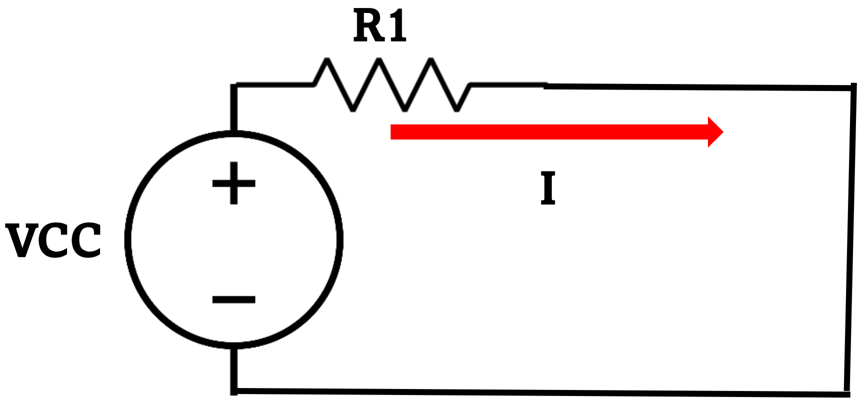
First Order Circuit Force Response

The circuit is in steady state and the respond will be constant



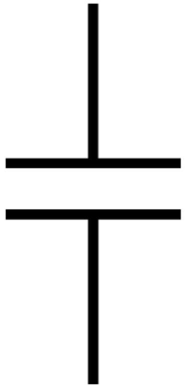






First Order Circuit Natural Response

Capacitor



Source free analysis

$$v(t) = v_0\left(e^{-\frac{t}{RC}}\right)$$

$$i(t) = \frac{v_0\left(e^{-\frac{t}{RC}}\right)}{R}$$

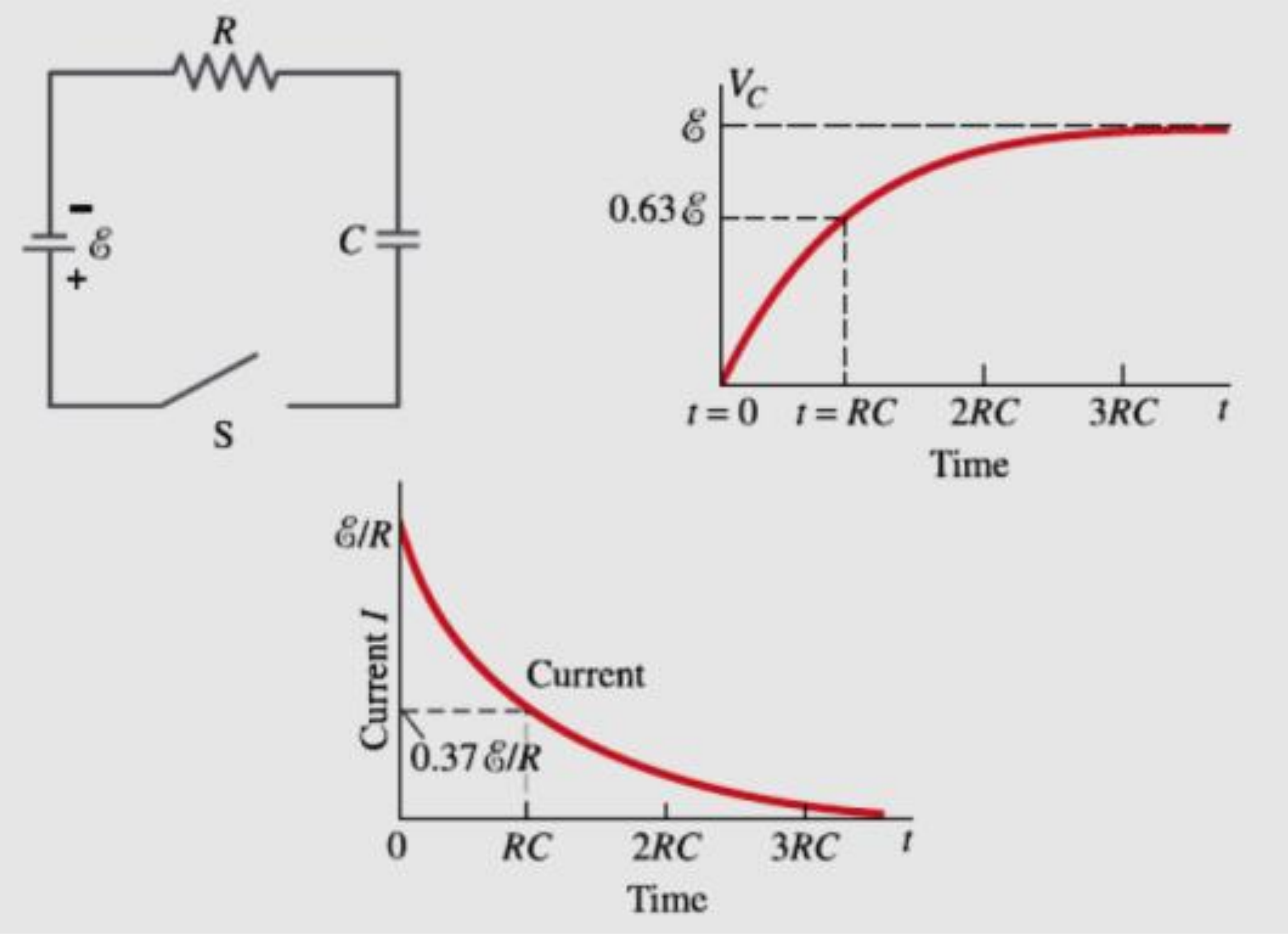
Inductor

Source free analysis

$$i(t) = i_0\left(e^{\frac{-t}{\frac{L}{R}}}\right)$$

$$v(t) = i_0\left(e^{\frac{-t}{\frac{L}{R}}}\right) \times R$$

RC Charging Circuit

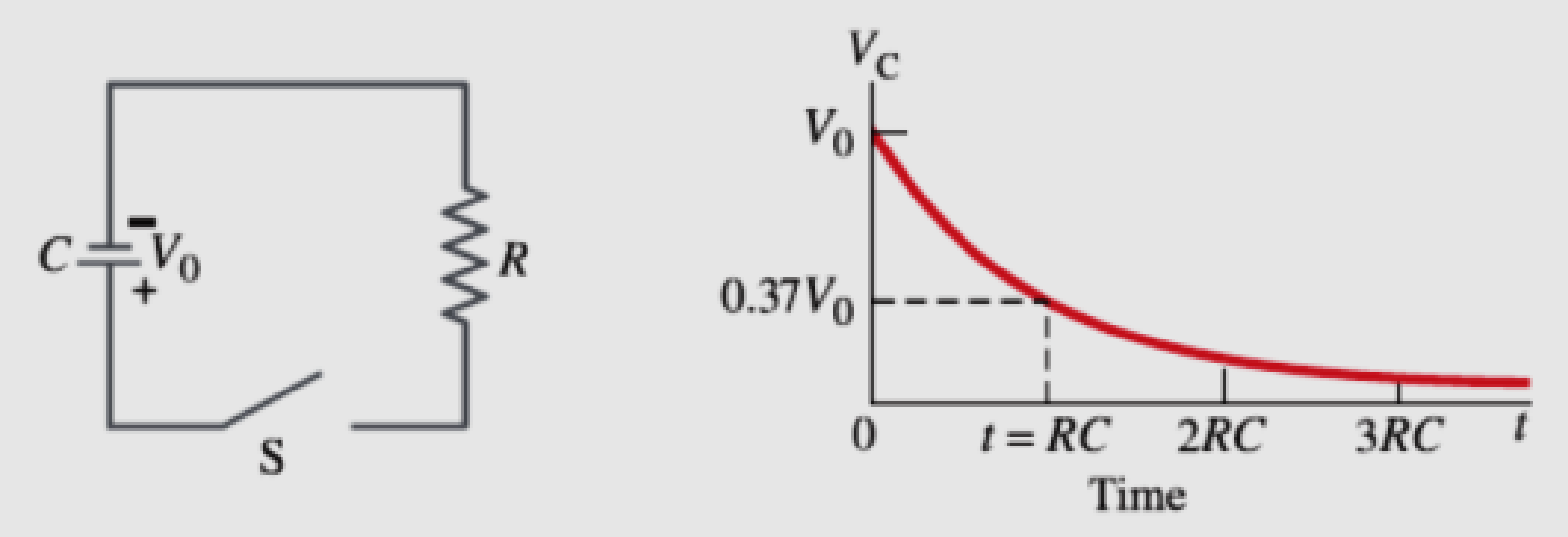


$$I = C\frac{dv}{dt}$$

$$V_C = \varepsilon(1 - e^{\frac{-t}{RC}})$$

$$I = \frac{\varepsilon}{R}e^{\frac{-t}{RC}}$$

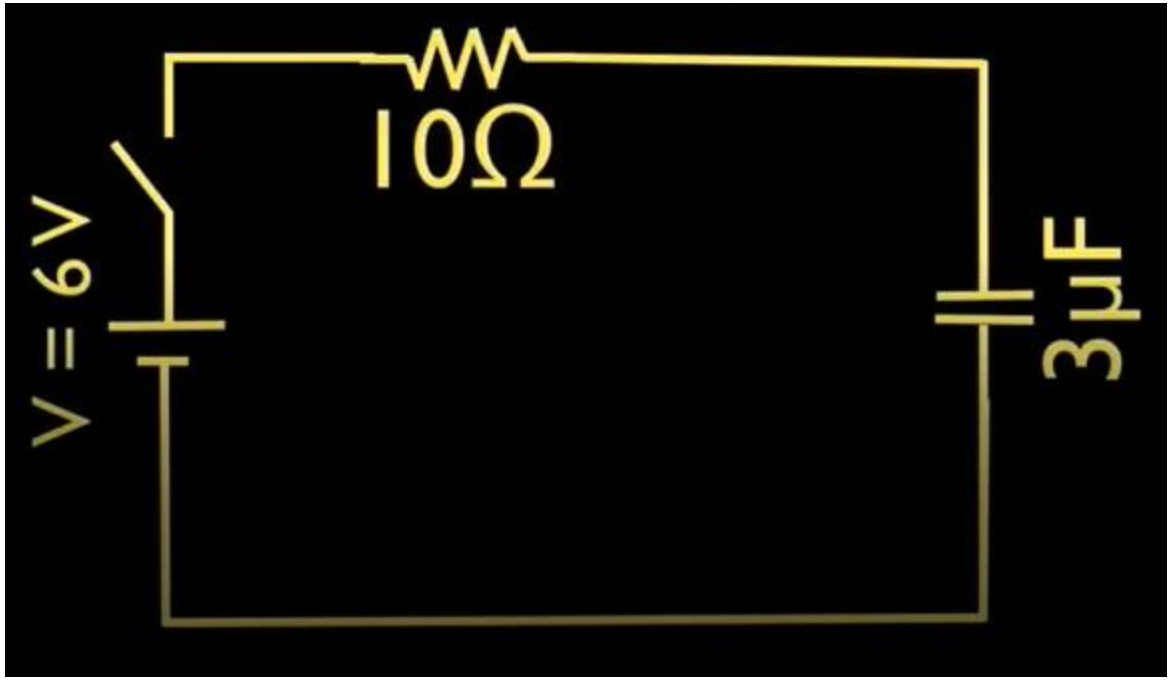
RC Discharging Circuit



$$V = V_0 e^{\frac{-t}{RC}}$$

$$I = I_0 e^{\frac{-t}{RC}}$$

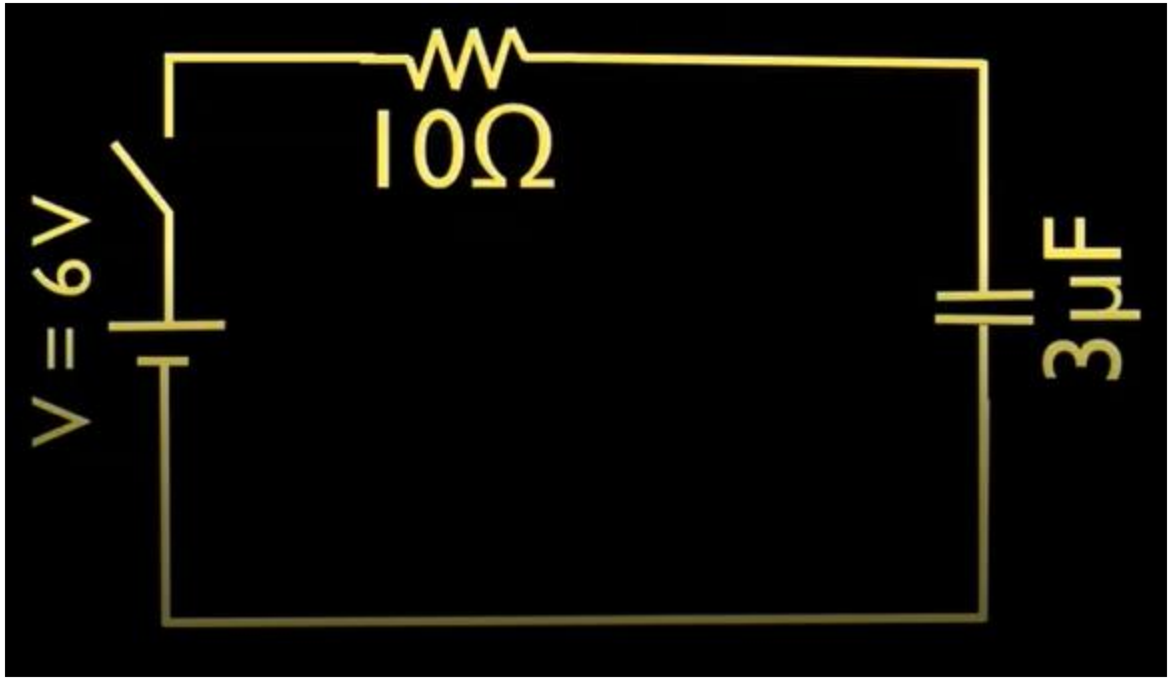
RC Circuit Example (Charging)



What happens immediately after the switch is closed (t=0) in the following?

1) Charge on Capacitor
2) Potential difference across capacitor
3) Potential difference across capacitor
4) Current through the circuit

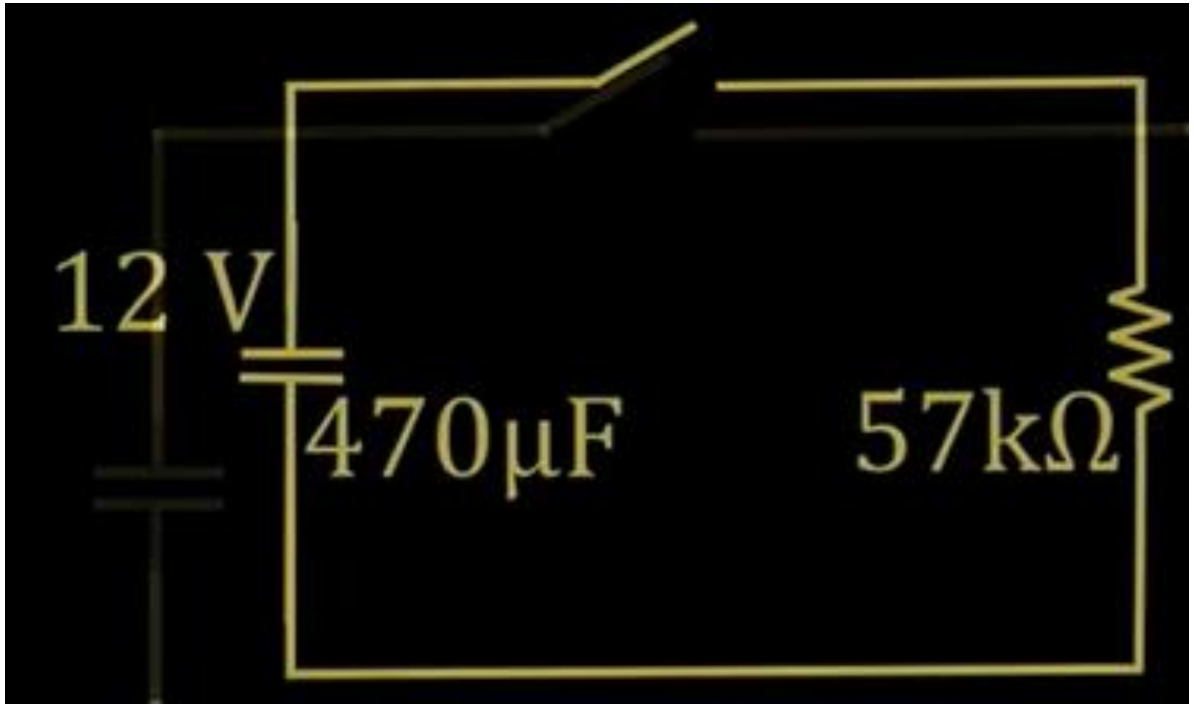
RC Circuit Example (Charging)



What happens after the switch is closed for a long time(t=∞) in the following?

1) Charge on Capacitor
2) Potential difference across capacitor
3) Potential difference across capacitor
4) Current through the circuit

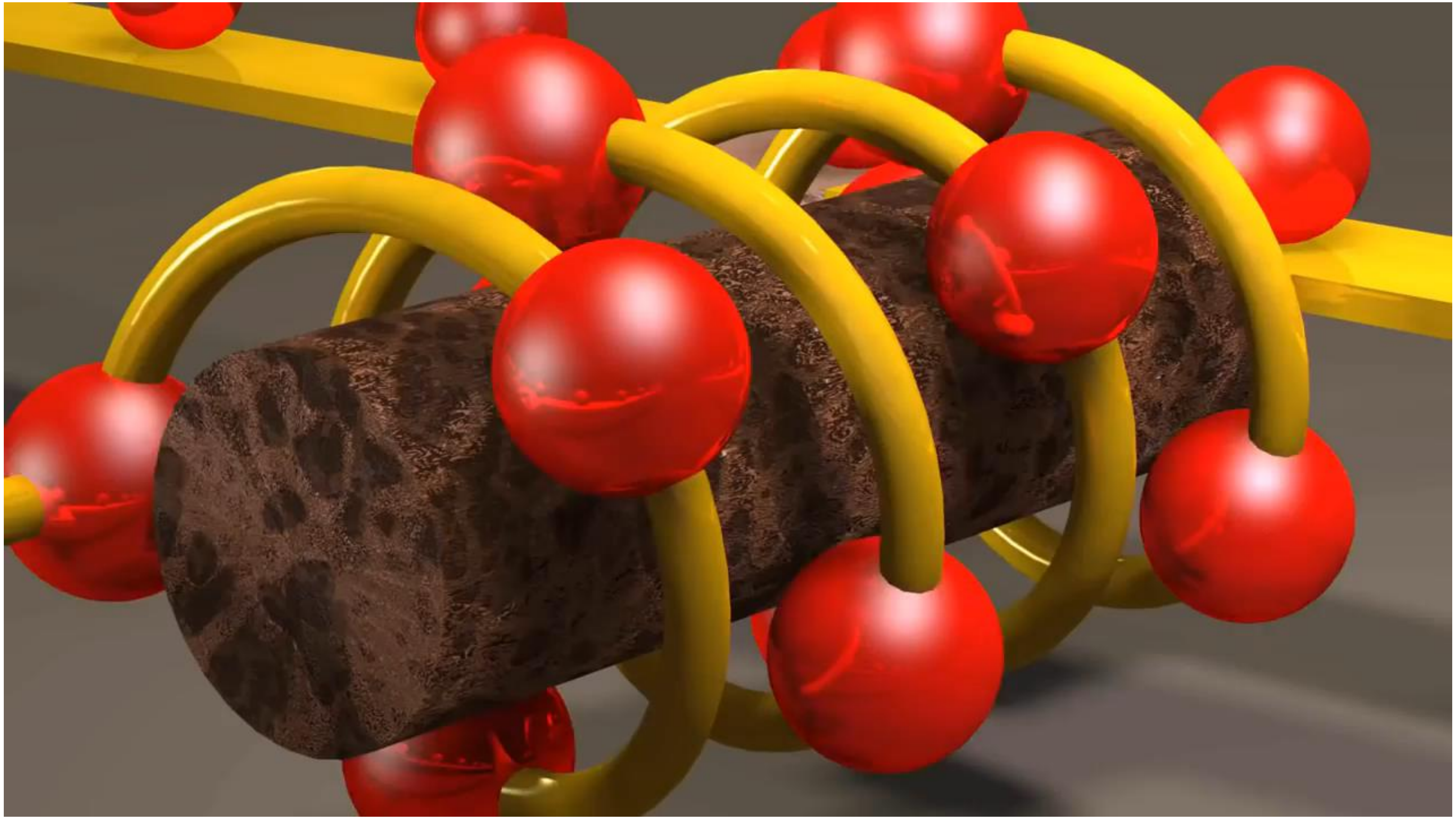
RC Circuit Example (Discharging)



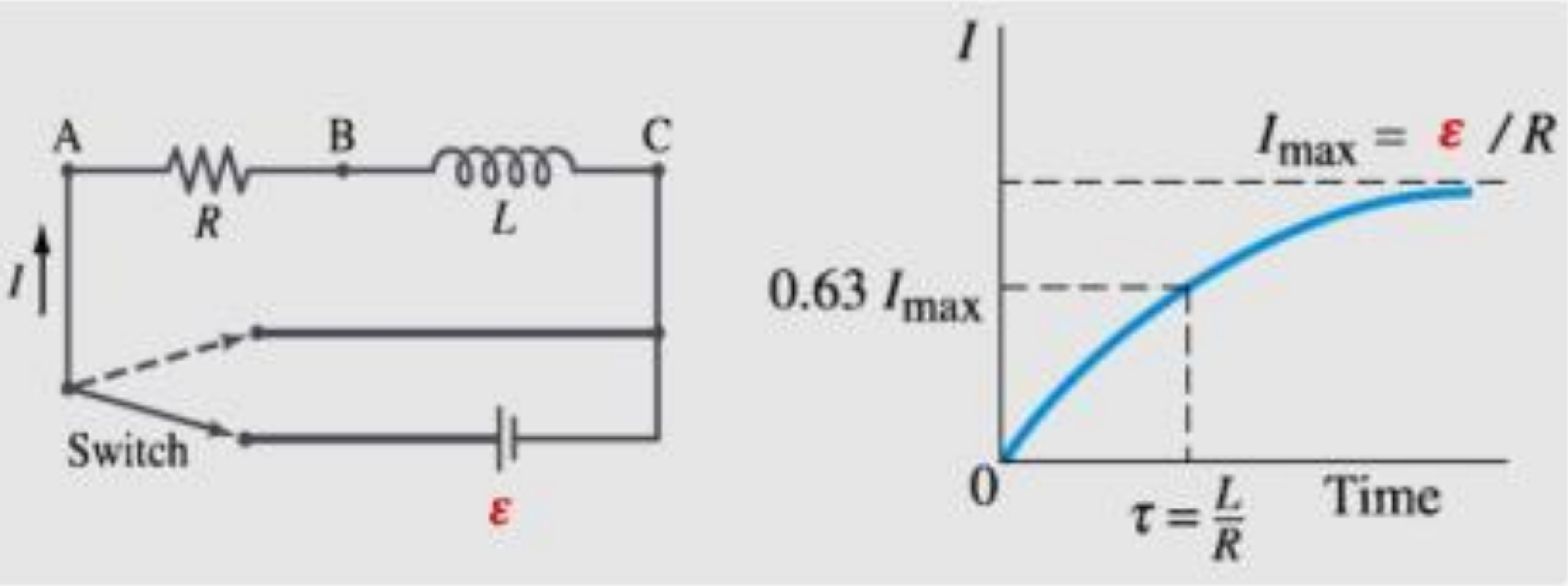
What happens if we remove the external power supply in the following

1) Voltage across capacitor after 1 time constant
2) Voltage across capacitor after 20 seconds
3) How much time it would take to fully discharge?

Inductor



Charging an Inductor

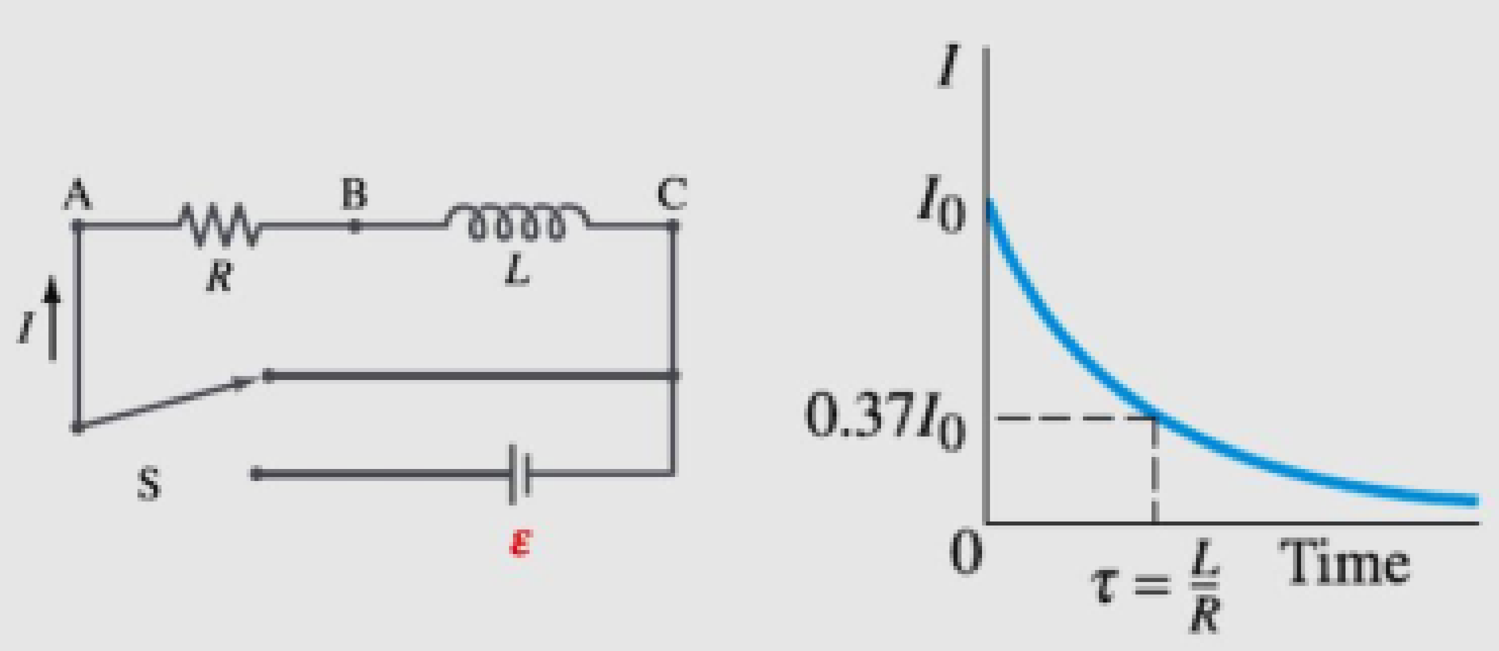


$$V = L\frac{dI}{dt}$$

$$V = \varepsilon e^{\frac{-tR}{L}}$$

$$I = \frac{\varepsilon}{R}(1 - e^{\frac{-tR}{L}})$$

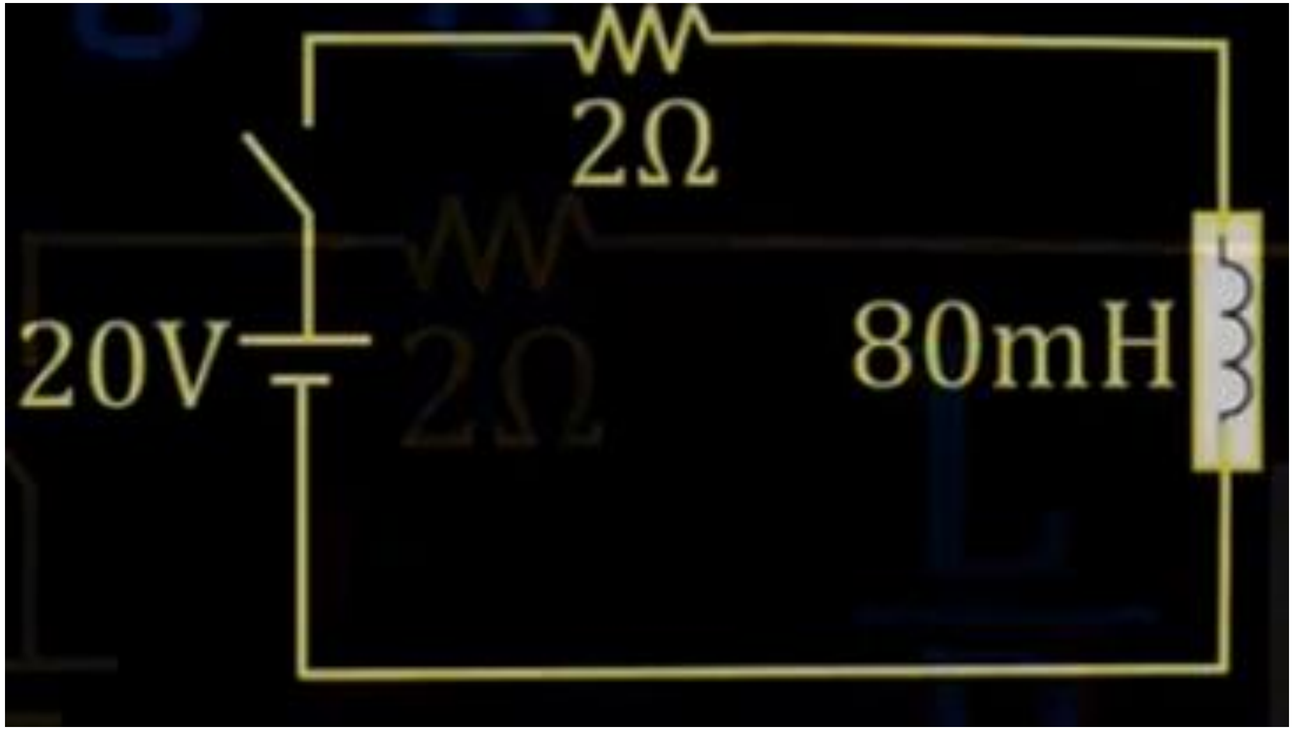
Discharging an Inductor



$$V = V_0 e^{\frac{-tR}{L}}$$

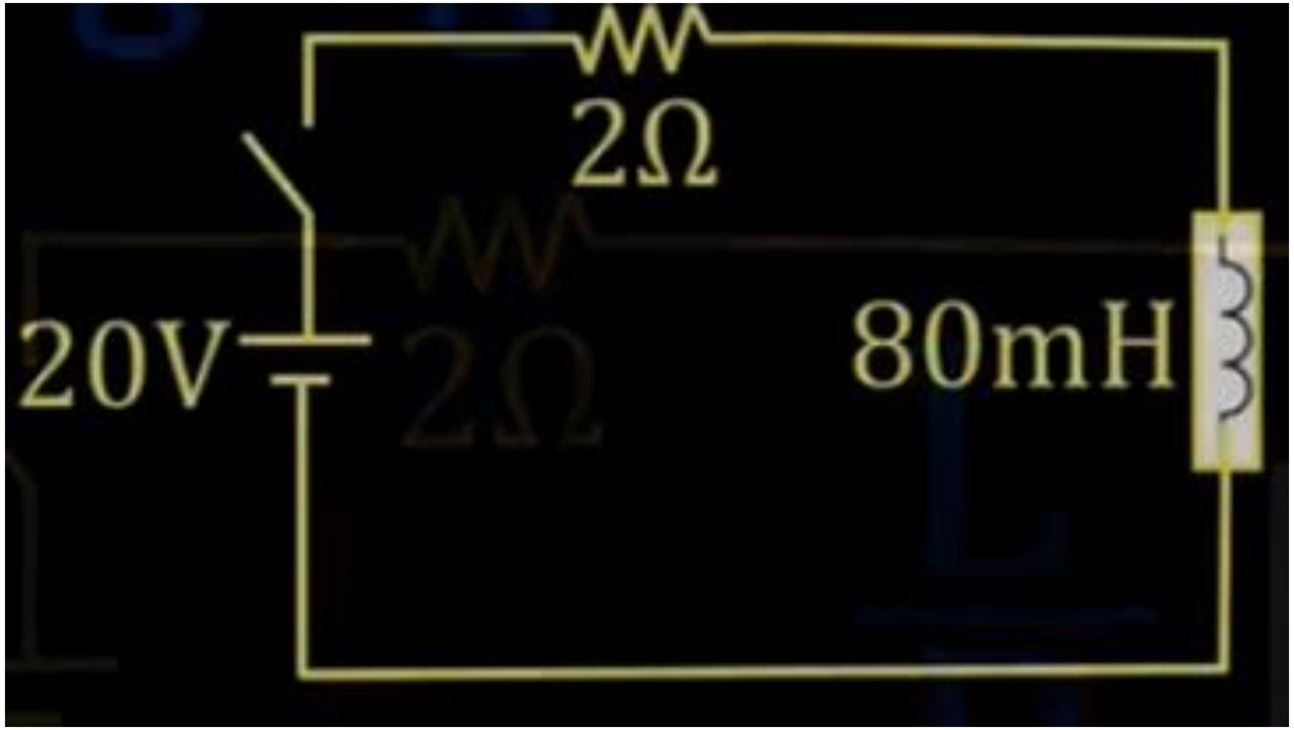
$$I = I_0 e^{\frac{-tR}{L}}$$

RL Circuit Example (Charging)



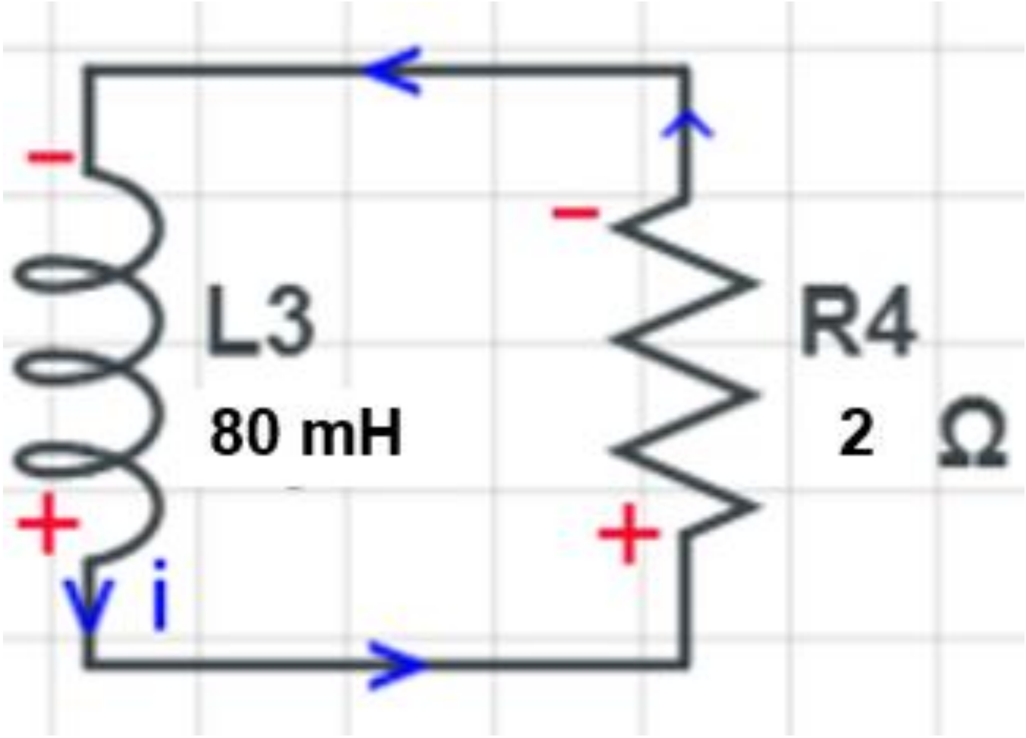
1) What will be the maximum current through the circuit (Steady state)?
2) When will the inductor be fully charged?
3) Induced voltage across the inductor after 25 ms?
4) Current through the circuit after 2 seconds?

RL Circuit Example (Charging)



1) At time t=0, voltage across inductor?
2) At time t= ∞, Current through the circuit?
3) What will be the maximum current through the circuit (Steady state)?
4) When will the inductor be fully charged?
5) Induced voltage across the inductor after 25 ms?
6) Current through the circuit after 2 seconds?

RL Circuit Example (Discharging)



1) What will be the maximum current through the circuit?
2) voltage across the resistor after 25 ms?
3) Current through the circuit after 2-time constants?

Thanks & have fun…