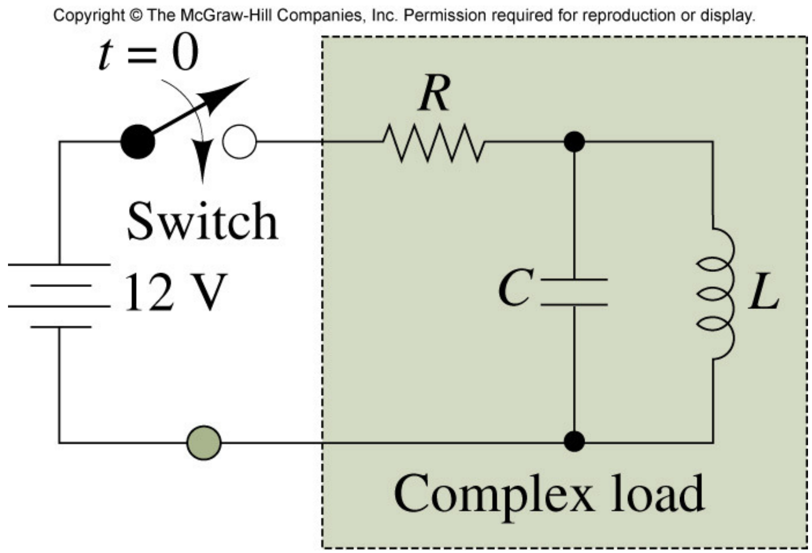
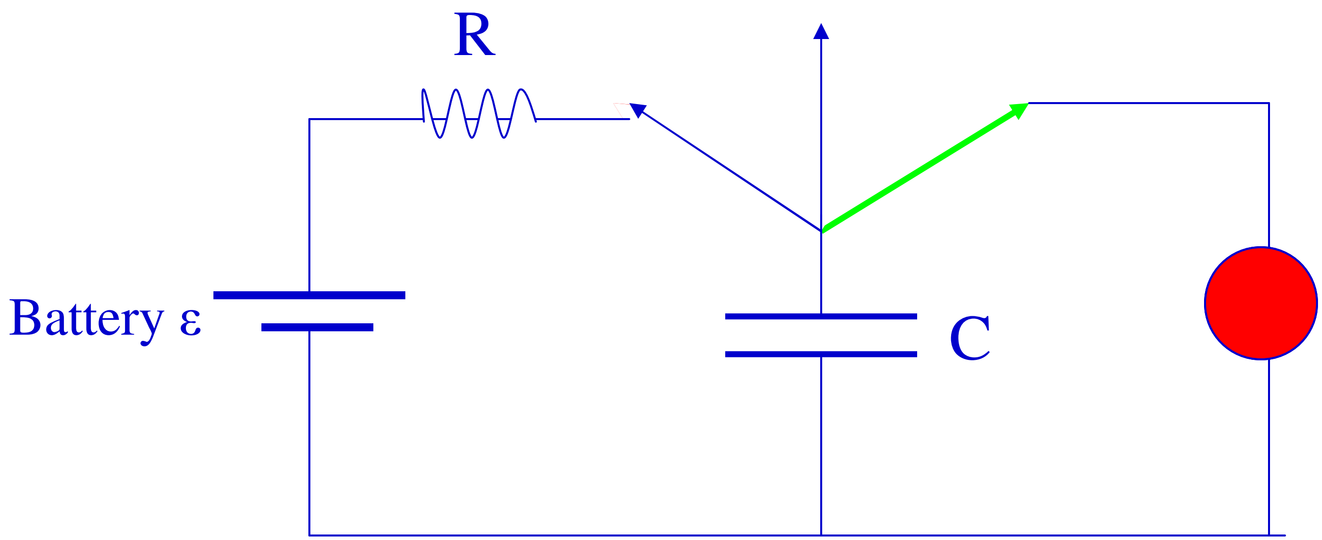
Transient Analysis

- Transient: transition region between two steady state, e.g. edges of square wave.
- Very important in digital circuit: delay.



Charging and discharging a capacitor



$$\varepsilon - v_R(t) - v_C(t) = 0$$

$$i_C = C\frac{dv_C}{dt}$$

$$i_C = i_R$$

$$C\frac{dv_C}{dt} = \frac{v_R(t)}{R} = \frac{\varepsilon - v_C(t)}{R}$$

$$\frac{dv_C}{\varepsilon - v_C(t)} = \frac{dt}{RC}$$

$$\ln\left(\varepsilon - v_C(t)\right) = -\frac{t}{RC} + A$$

$$\varepsilon - v_C(t) = e^A e^{-\frac{t}{RC}} = Be^{-\frac{t}{RC}}$$

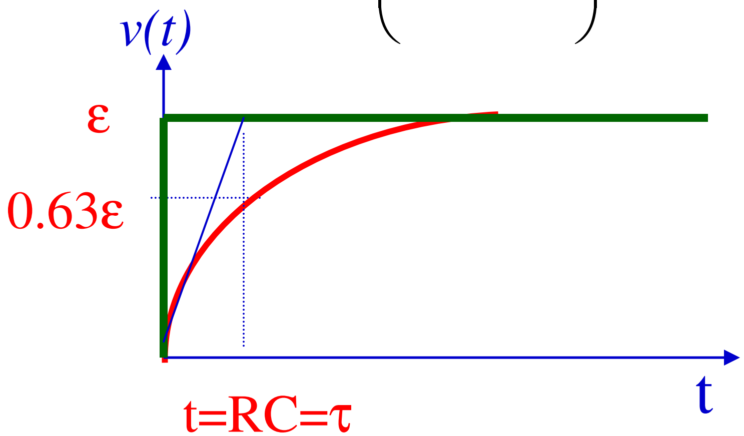
$$\text{at } t = 0, v_C(t) = 0$$

$$\varepsilon = Be^0 = B$$

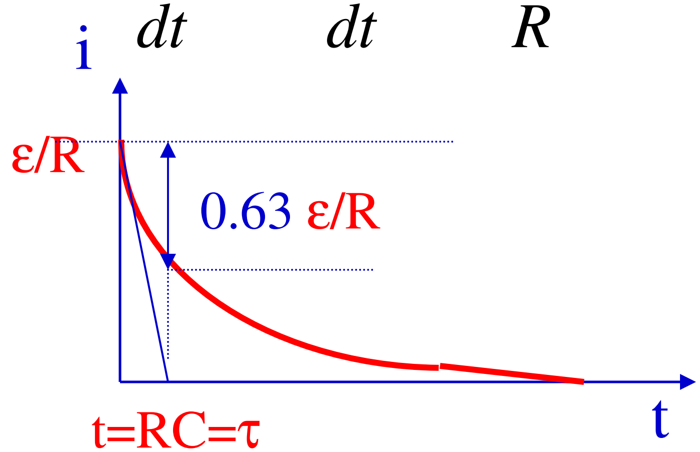
$$v_C(t) = \varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$

Charging a Capacitor

$$v(t) = \varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$



$$i = \frac{dq}{dt} = \frac{Cdv(t)}{dt} = \frac{\varepsilon}{R}e^{-\frac{t}{RC}}$$

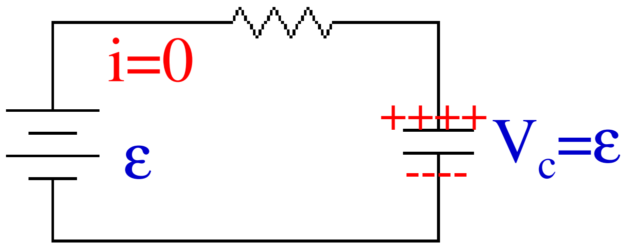


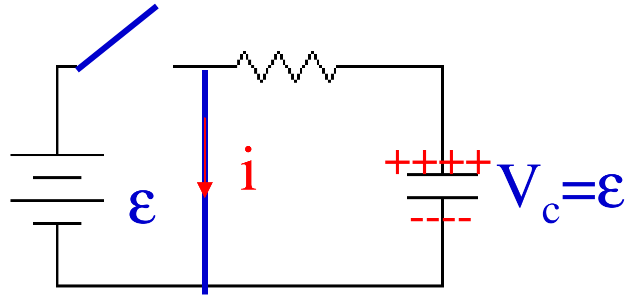
Time constant (τ): time needs to charge a capacitor to 63% of its full charge.

The larger the RC, the longer it takes to charge a capacitor.

The larger the R value, the smaller the current is in the circuit.
The larger the C value, the more the charge the capacitor can hold

Discharging a Capacitor

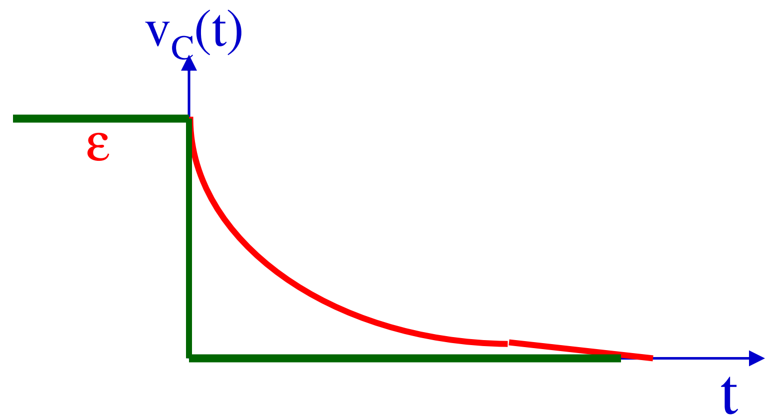




t = 0

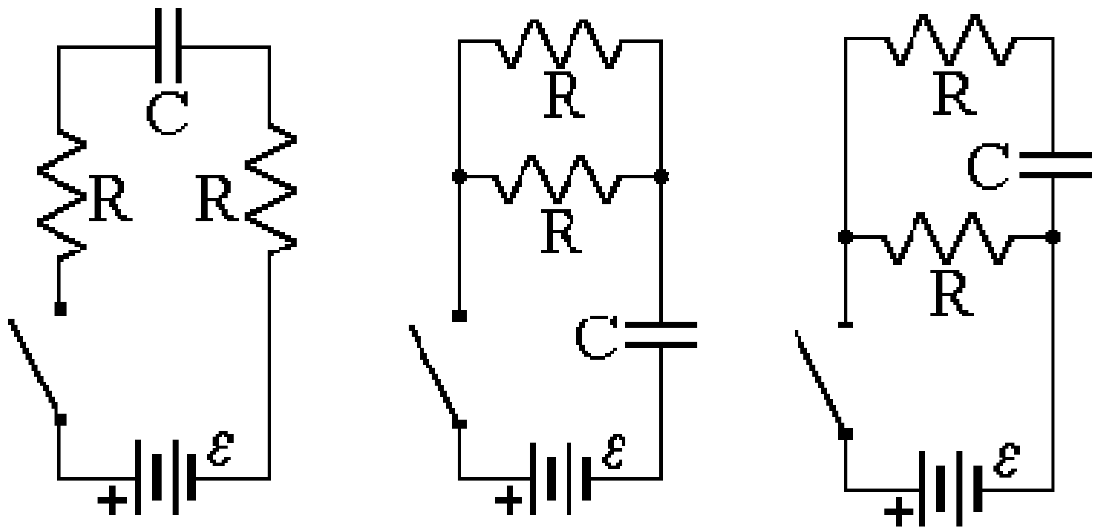
$$v(t) = \varepsilon e^{-\frac{t}{RC}}$$

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



Concept Check: RC circuit

Charging Capacitors

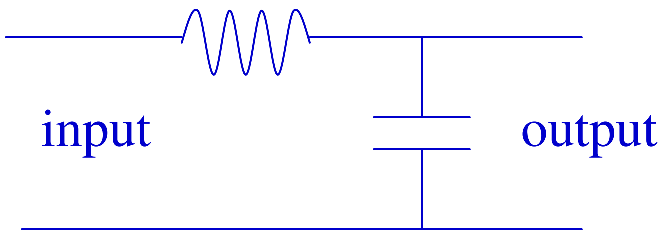


(a) (b) (c)

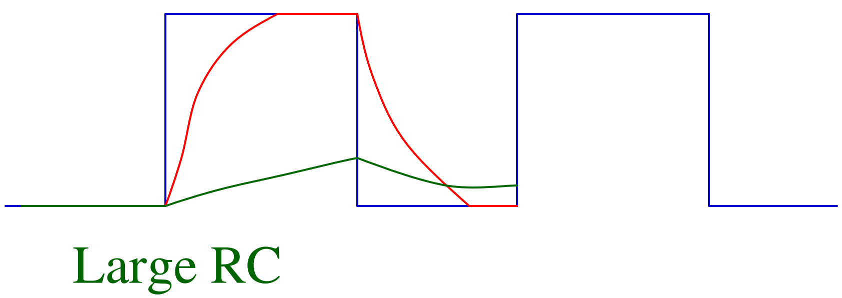
Which configuration has the largest final charge on the capacitor?
Which capacitor charges faster?

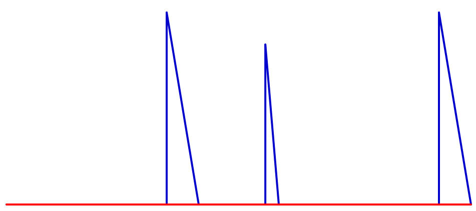
Answers:

Delay is very useful for other circuit



- No Sudden Change in voltage, i.e. voltage has to change continuously!



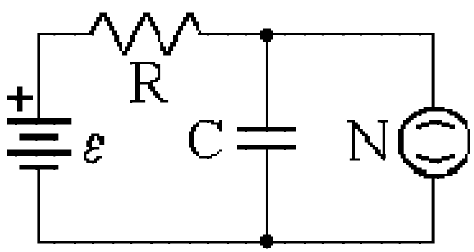


Rectifying circuit: convert ac to dc signal.

Previously solving ac circuit, we all assumed that delay is negligible

Example

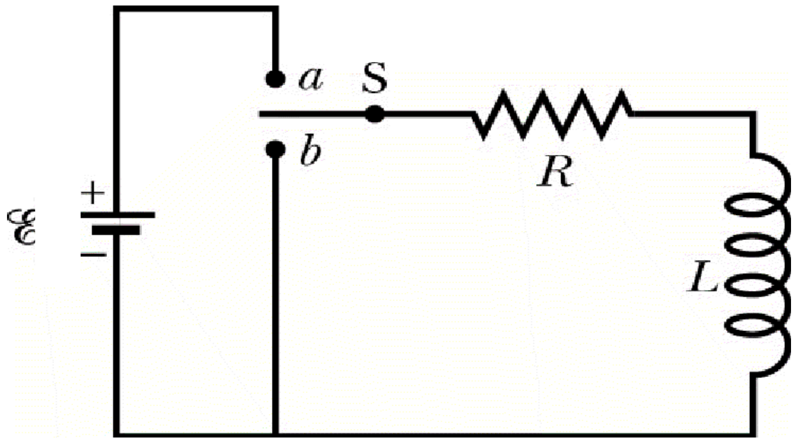
28-52P. The flashing lights seen on barricades at street work and construction sites are driven by a relaxation oscillator circuit as shown in the figure, with *N* being a neon lamp. The lamp is nonconducting until the voltage across it (And the capacitor also) rises to a value of 72 V whereupon it "ignites," dropping its resistance almost instantly to zero and discharging the capacitor. Then the lamp again becomes nonconducting and the process repeats. If the *emf* = 95 V and C = 0.150 microF, what should *R* be for the lamp to flash every 0.5 sec?



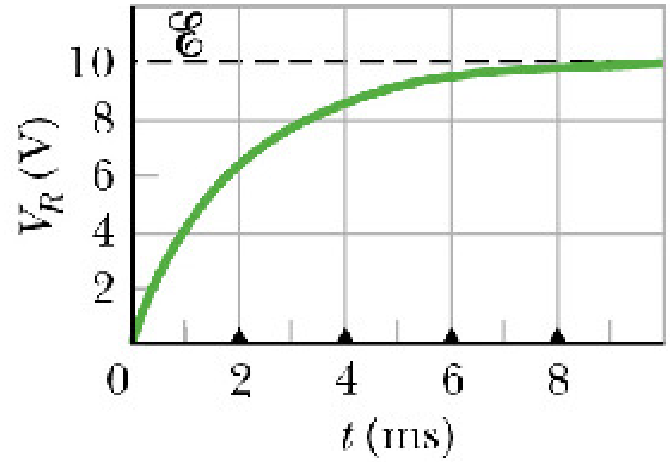
$$V_c = \varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$

$$R = \frac{t}{C\ln\left(\frac{\varepsilon}{\varepsilon - V_L}\right)} = \frac{0.5}{0.15\times10^{-6}\ln\left(\frac{95.0}{95.0-72.0}\right)}$$

$$= 2.35\times10^{6}\,\Omega$$



RL Circuit



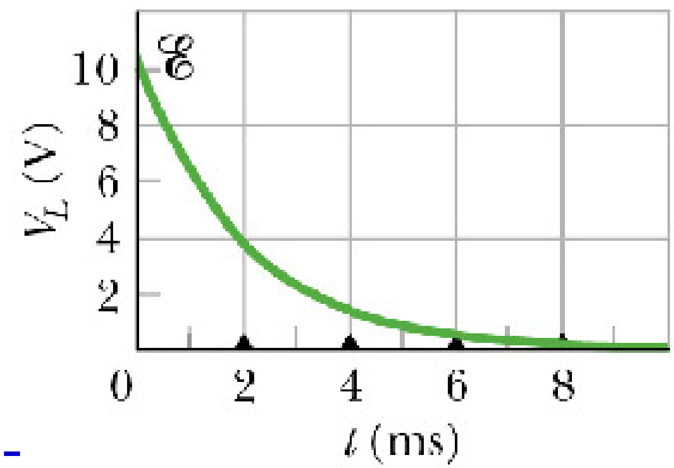
(a)

Switch to position *a*

$$\varepsilon - V_L - iR = 0 \qquad \varepsilon - iR = L\frac{di}{dt}$$

$$\varepsilon - L\frac{di}{dt} - iR = 0 \qquad \frac{1}{L}dt = \frac{di}{\varepsilon - iR}$$

t=0, i=0 $\quad i = \frac{\varepsilon}{R}\left(1 - e^{-Rt/L}\right)$ $\quad \tau$=L/R



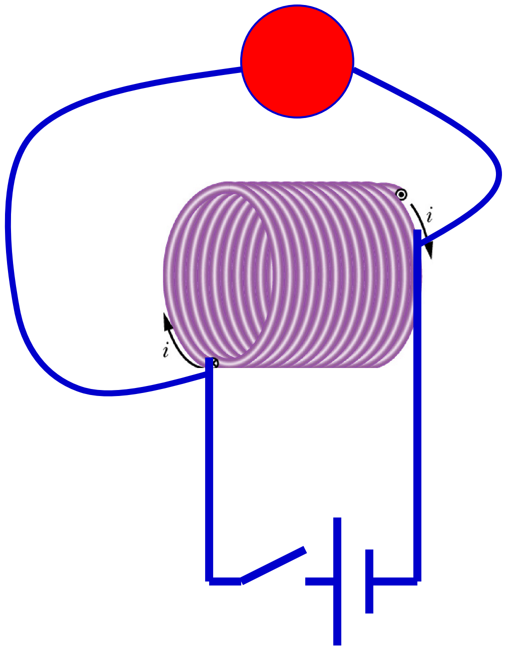
(b)

Switch to position *b* $\quad i = \frac{\varepsilon}{R}e^{-Rt/L} = i_0 e^{-Rt/L}$

Current (i_L) must be continuous, i.e. i+=i-

Concept Check

A battery is connected to a solenoid. When the switch is opened, the light bulb



1. Remain off
2. Goes off
3. Slowly dims out
4. Keeps burning as brightly as it did before the switch was opened.
5. Flares up brightly, then dims and goes out

Answer