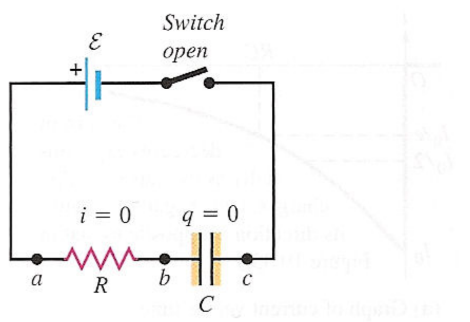
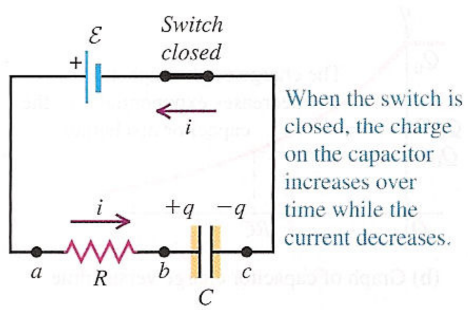
THREE IMPORTANT DC CIRCUITS

1. R-C Circuit (Resistor-Capacitor)



(a) Capacitor initially uncharged



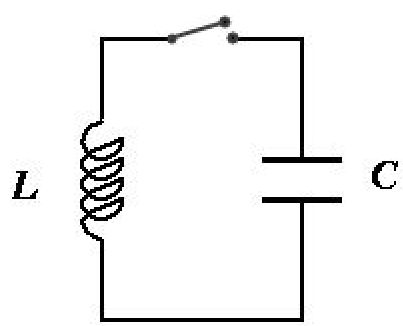
(b) Charging the capacitor

When switch is closed, the time T_C it takes for the capacitor to charge roughly given by

$$T_C = RC$$

This is the about the same time it takes for the capacitor to discharge.

2. L-C Circuit (Inductor-Capacitor)

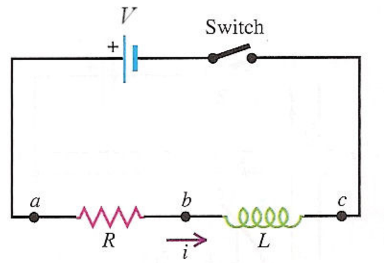


Assume the capacitor is fully charged. This means that one side of the capacitor has an excess of electrons. When the switch is closed, many of these electrons will travel to the other side of the capacitor (in order to equalize the charge between the sides). The inductor causes electron flow to continue longer than it otherwise would. This results in an excess of electrons on the other side of the capacitor (instead of an equalization). The process repeats in other direction. The frequency f at which charge sloshes back and forth between the two sides of the capacitor is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

This circuit is used in radio tuners.

3. L-R Circuit (Inductor-Resistor)



When the switch is closes, the time T_M it takes for the current to reach its maximum value of V/R is roughly given by

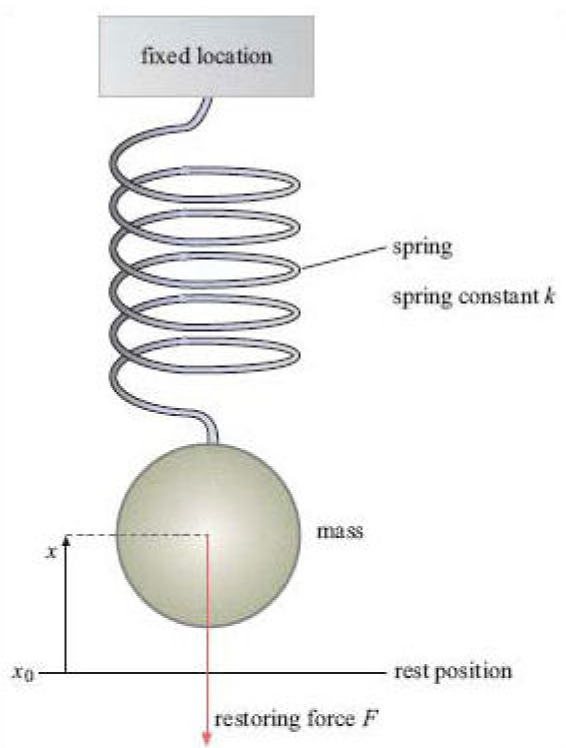
$$T_M = \frac{L}{R}$$

If we "short out" this circuit by connecting points "*a*" and "*c*" (see figure) with a wire, the time for the current to die away is also about *L/R*.

UNDERSTANDING CIRCUITS INTUITIVELY

The analogy between circuits and a physical oscillator

Our physical oscillator will be a mass attached to a spring in a viscous fluid.

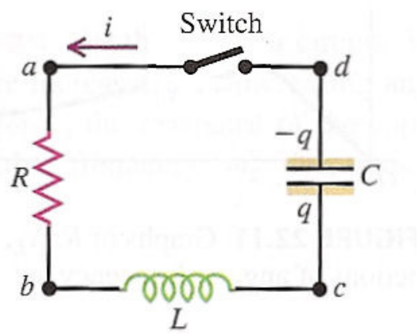


Mathematically, a circuit with a resistor, inductor, and capacitor in series behaves the same as an oscillator.

To use this analogy, you need the following table of analogs.

Circuit Property	Analogous Oscillator Property
q (charge)	x (displacement from equilibrium)
I (current)	v (velocity)
L (inductance)	m (mass)
R (resistance)	α (coefficient of friction)
1/C (inverse capacitance)	k (spring stiffness constant)
V (applied voltage)	F (applied force)

Example – R-L-C Circuit.



Q. If the capacitor is charged, what will happen when the switch is closed?

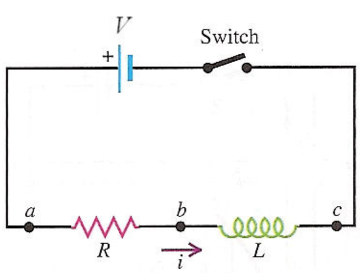
Answer. The charge on each side of the capacitor will alternatively swing between its maximum and minimum values.
The frequency of this oscillation will be

$$f = \frac{1}{2\pi\sqrt{LC}}.$$

Then magnitude of the maximum charge on the capacitor will gradually decline until it is zero.

How is this obvious? The circuit is analogous to a physical oscillator in a viscous fluid. We know the frequency from the L-C circuit (above). According to the analog table, the resistor just acts as friction (molasses). Friction always damps down oscillations until they disappear.

Example – L-R Circuit



Q. What happens when the switch is closed.

Answer. Current reaches a maximum value and remains steady.

Why? According to the table this is analogous to a mass (L) subjected to a frictional force (R), and a constant applied force (V). [There is no spring, because there is no capacitor.] This describes a skydiver who has a mass, is being pulled by a constant force (gravity), and is experiencing friction (air resistance). He reaches a terminal velocity (analogous to a maximum steady current).