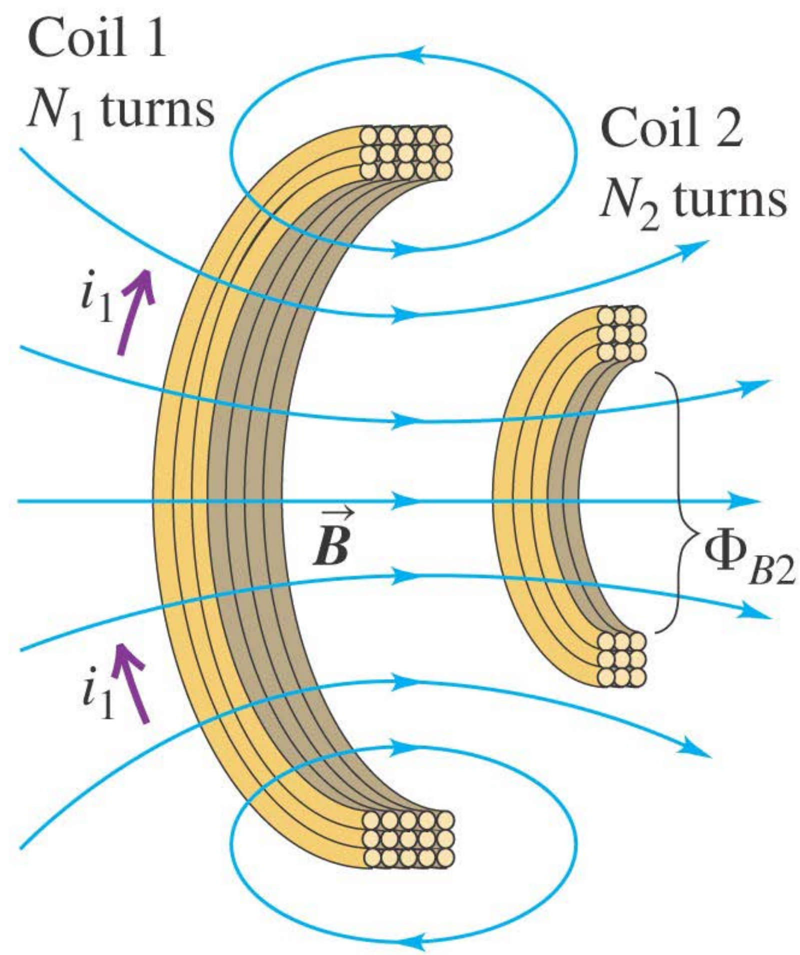
PHYS121H + PHYS122-Lecture 12: Inductance and RLC Circuits

- Final Exam Date/Logistics
- Today: Chap 30:
  - a) Mutual Induction
  - b) Self Induction
  - c). RC circuit
  - d). LC circuit
  - e). RLC circuit

Mutual inductance

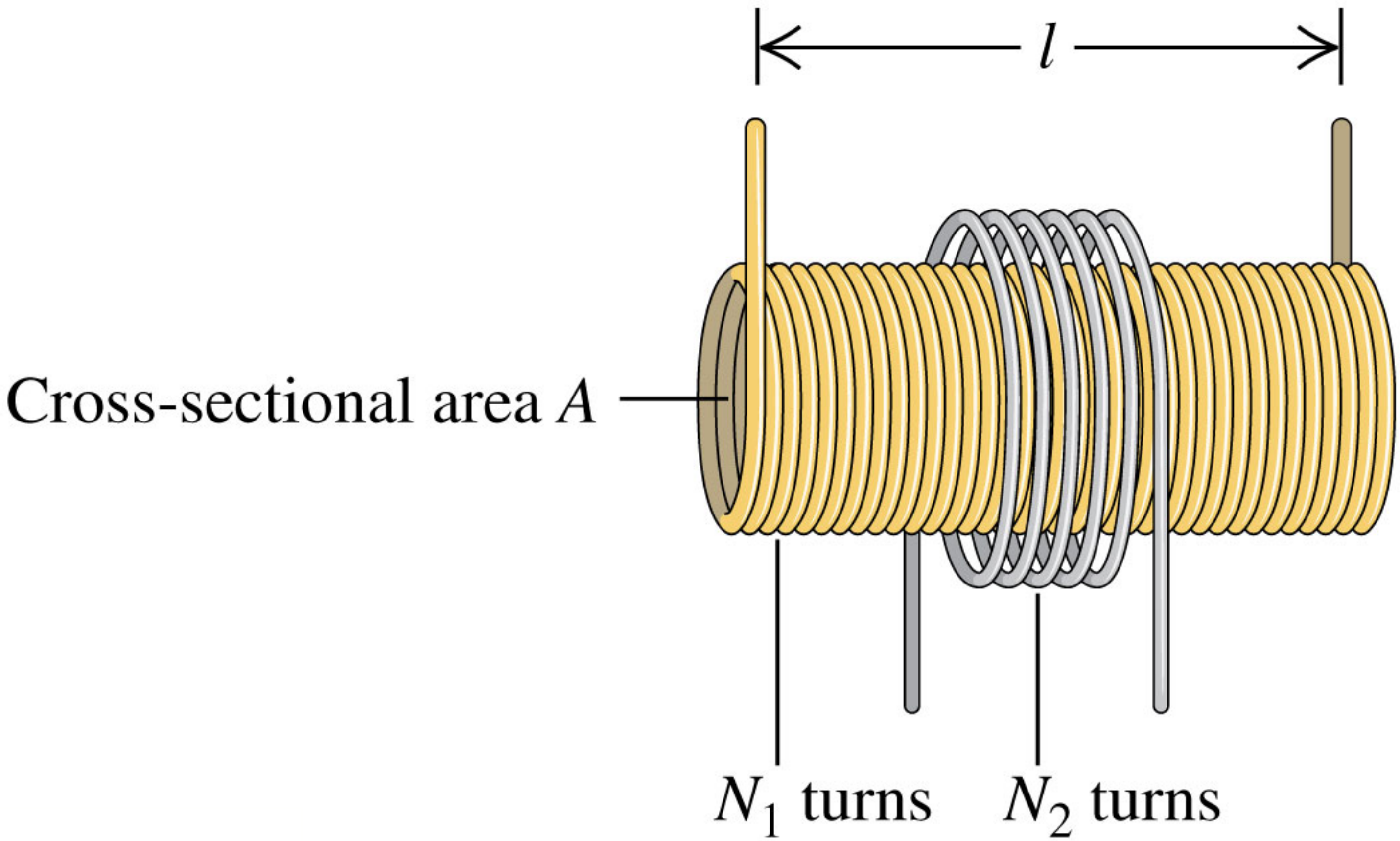
- *Mutual inductance*: A changing current in one coil induces a current in a neighboring coil. See Figure 30.1 at the right.
- Follow the discussion of mutual inductance in the text.

Mutual inductance: If the current in coil 1 is changing, the changing flux through coil 2 induces an emf in coil 2.



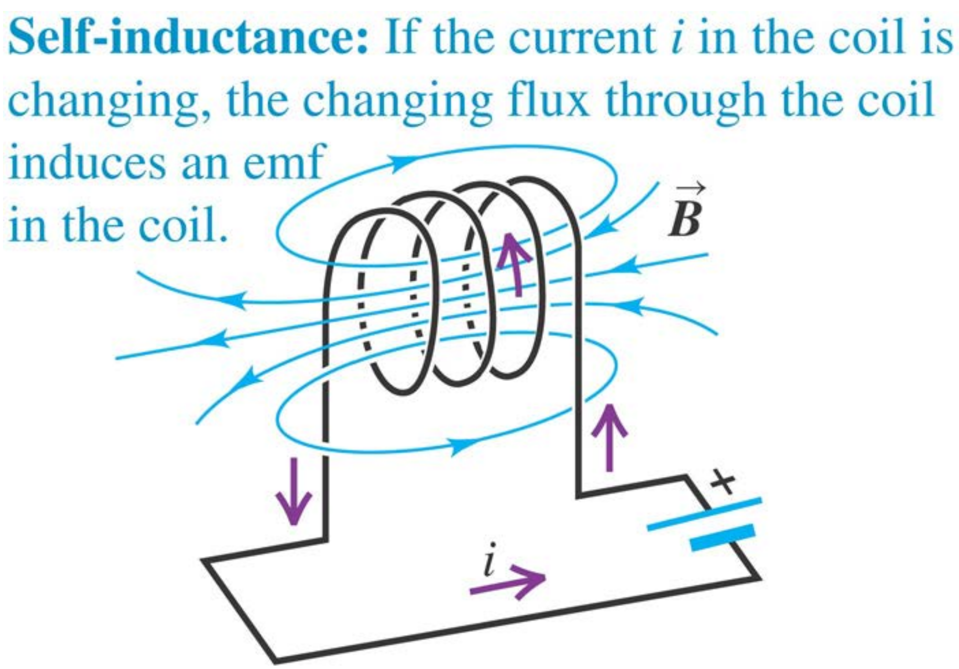
Mutual inductance examples

- Follow Example 30.1, which shows how to calculate mutual inductance. See Figure 30.3 below.
- Follow Example 30.2, which looks at the induced emf.



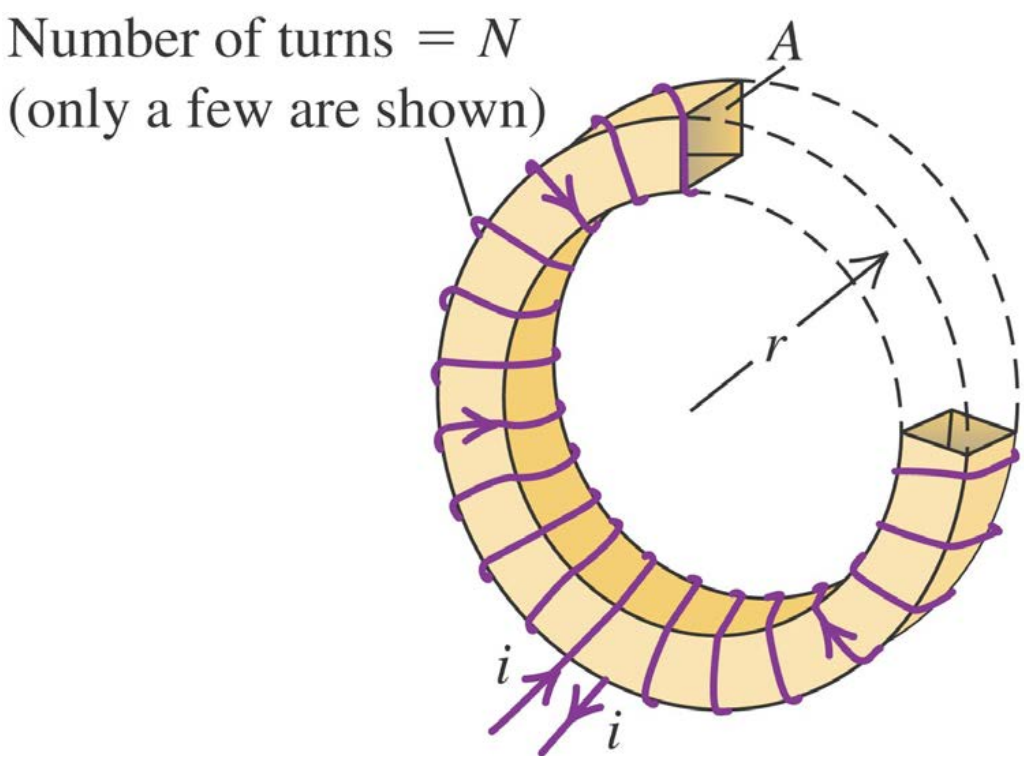
Self-inductance

- *Self-inductance*: A varying current in a circuit induces an emf in that same circuit. See Figure 30.4 below.
- Follow the text discussion of self-inductance and inductors.



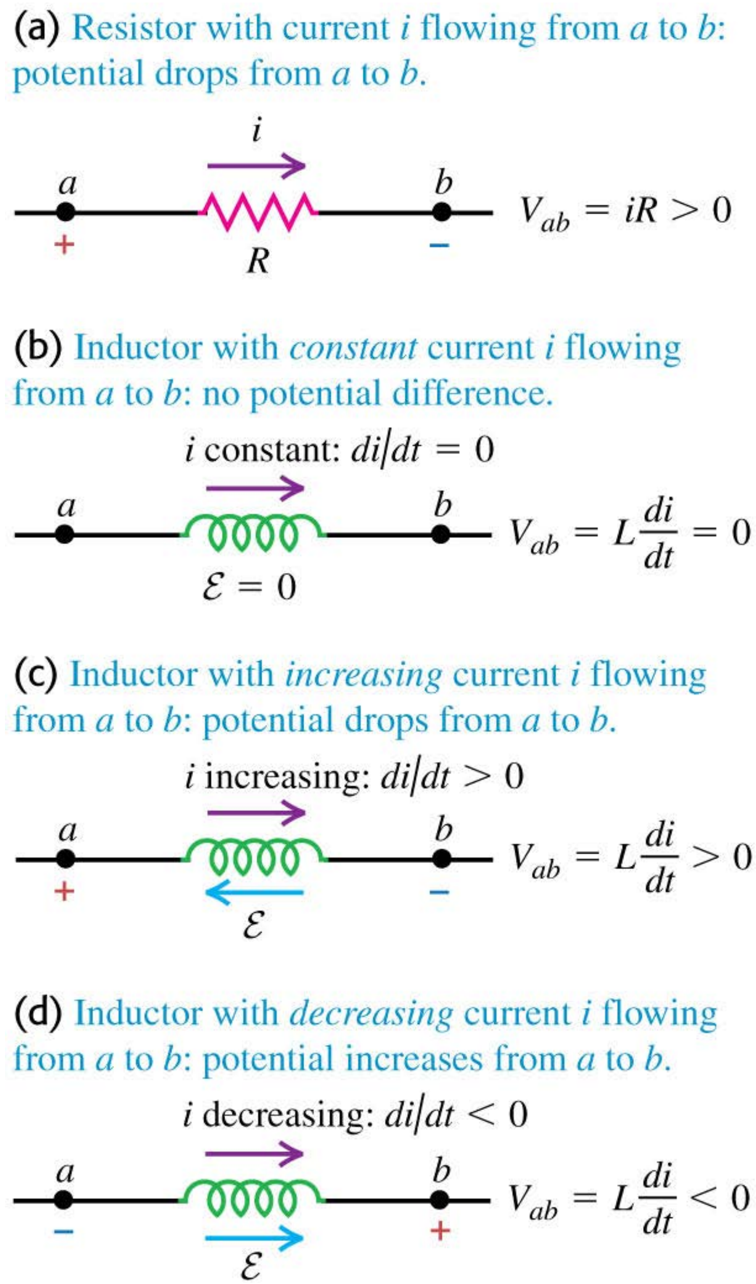
Calculating self-inductance and self-induced emf

- Follow Example 30.3 using Figure 30.8 below.
- Follow Example 30.4.



Potential across an inductor

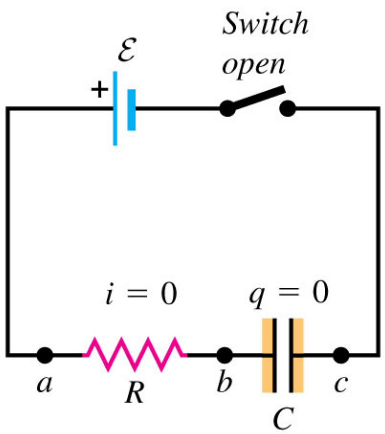
- The potential across an inductor depends on the rate of change of the current through it.
- Figure 30.6 at the right compares the behavior of the potential across a resistor and an inductor.
- The self-induced emf does *not* oppose current, but opposes a *change* in the current.



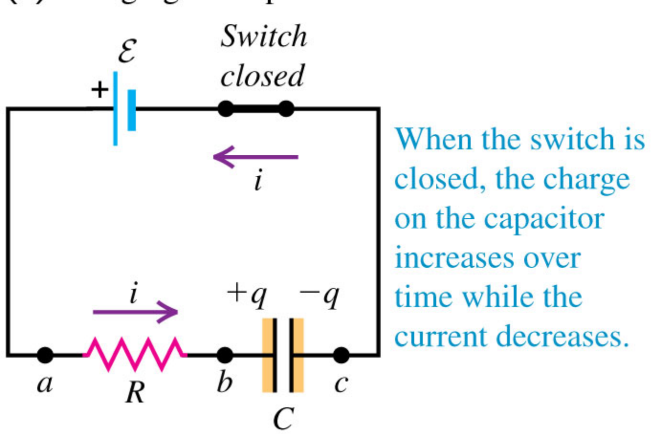
Charging a capacitor

- Read the discussion of charging a capacitor in the text, using Figures 26.20 and 26.21 below.
- The *time constant* is $\tau = RC$.

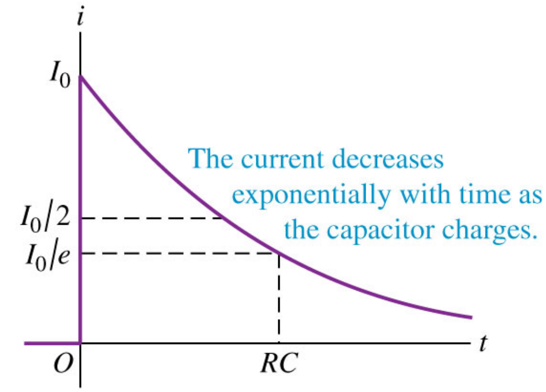
(a) Capacitor initially uncharged



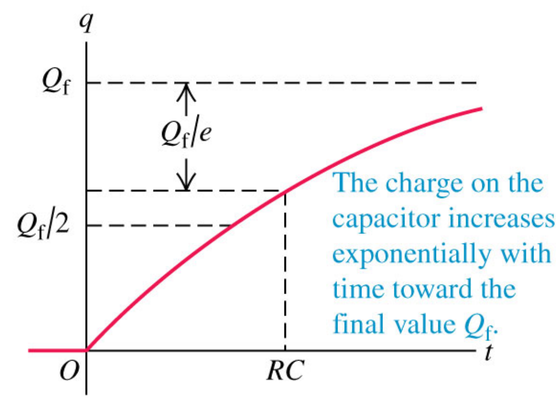
(b) Charging the capacitor



(a) Graph of current versus time for a charging capacitor

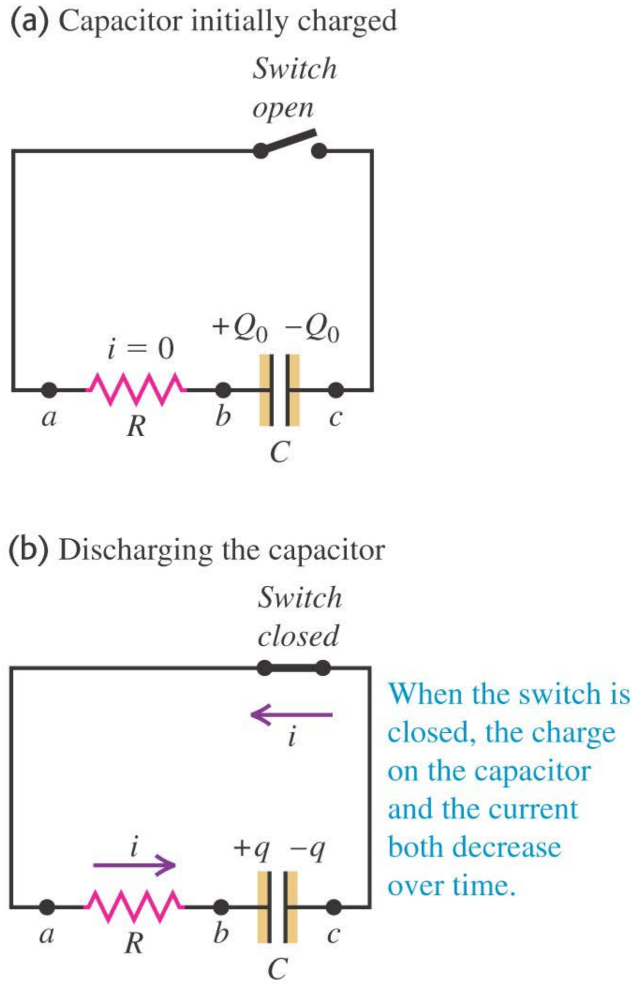


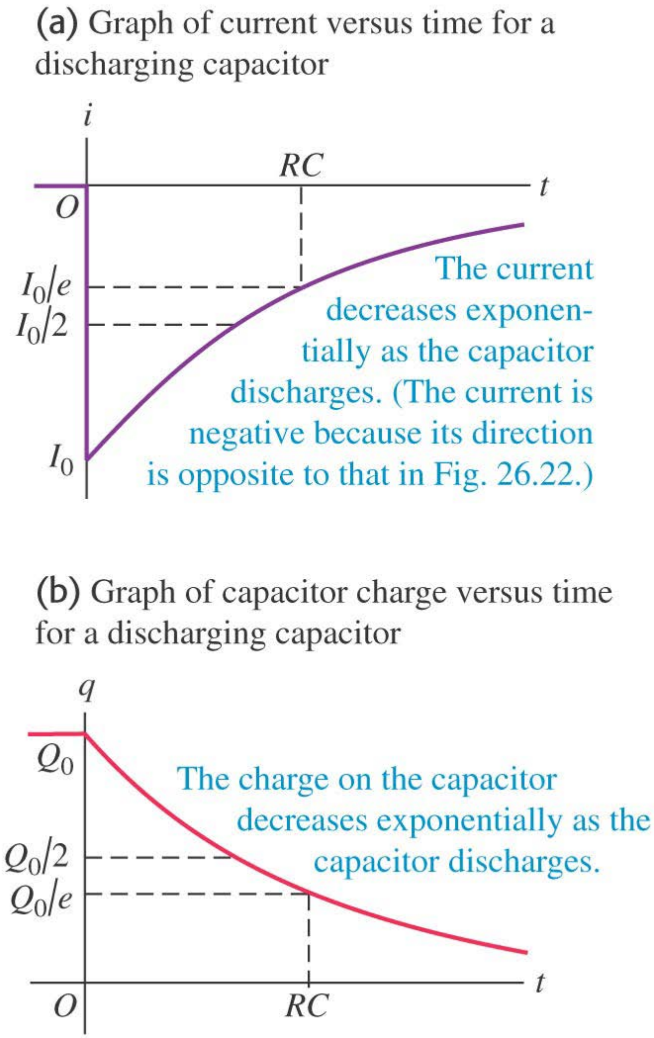
(b) Graph of capacitor charge versus time for a charging capacitor



Discharging a capacitor

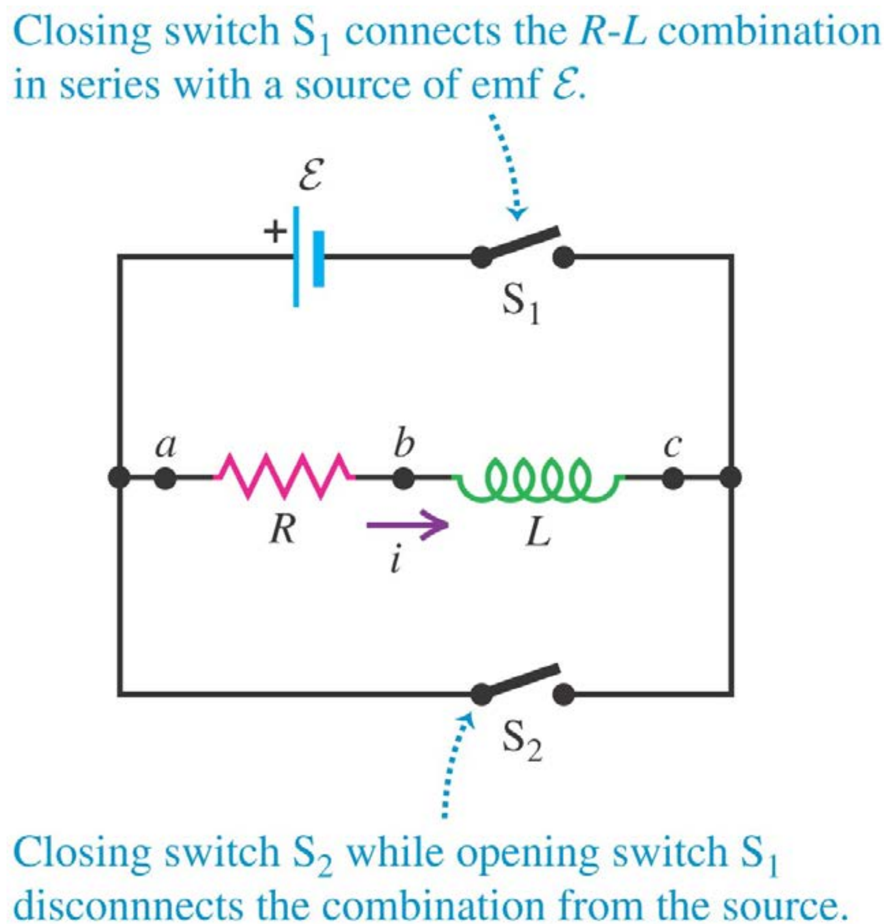
- Read the discussion of discharging a capacitor in the text, using Figures 26.22 and 26.23 below.
- Follow Examples 26.12 and 26.13.





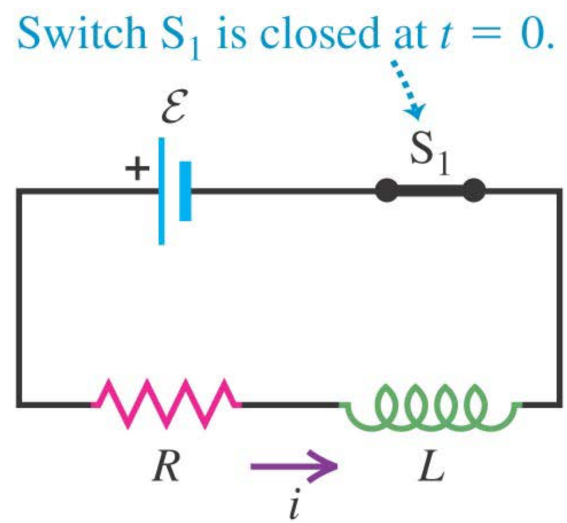
The *R-L* circuit

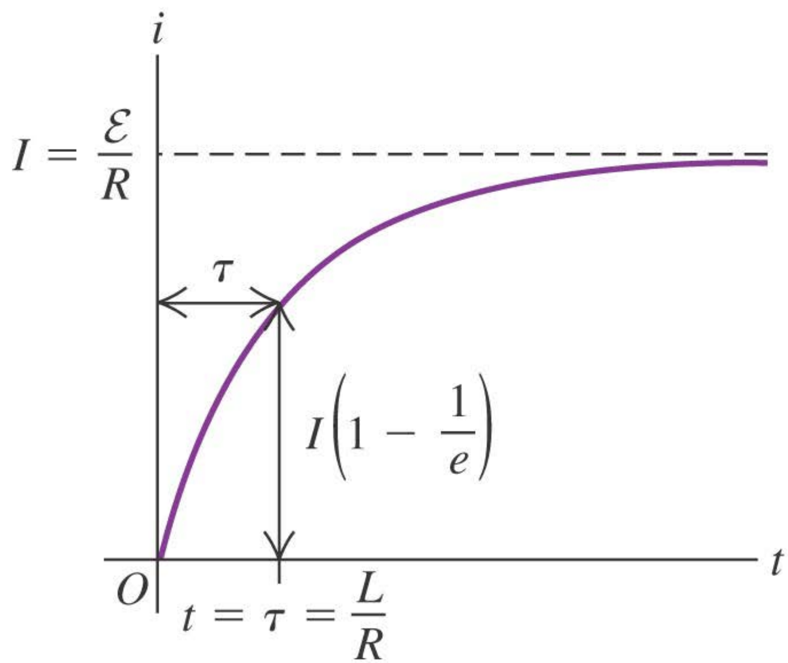
- An *R-L circuit* contains a resistor and inductor and possibly an emf source.
- Figure 30.11 at the right shows a typical *R-L* circuit.
- Follow Problem-Solving Strategy 30.1.



Current growth in an *R-L* circuit

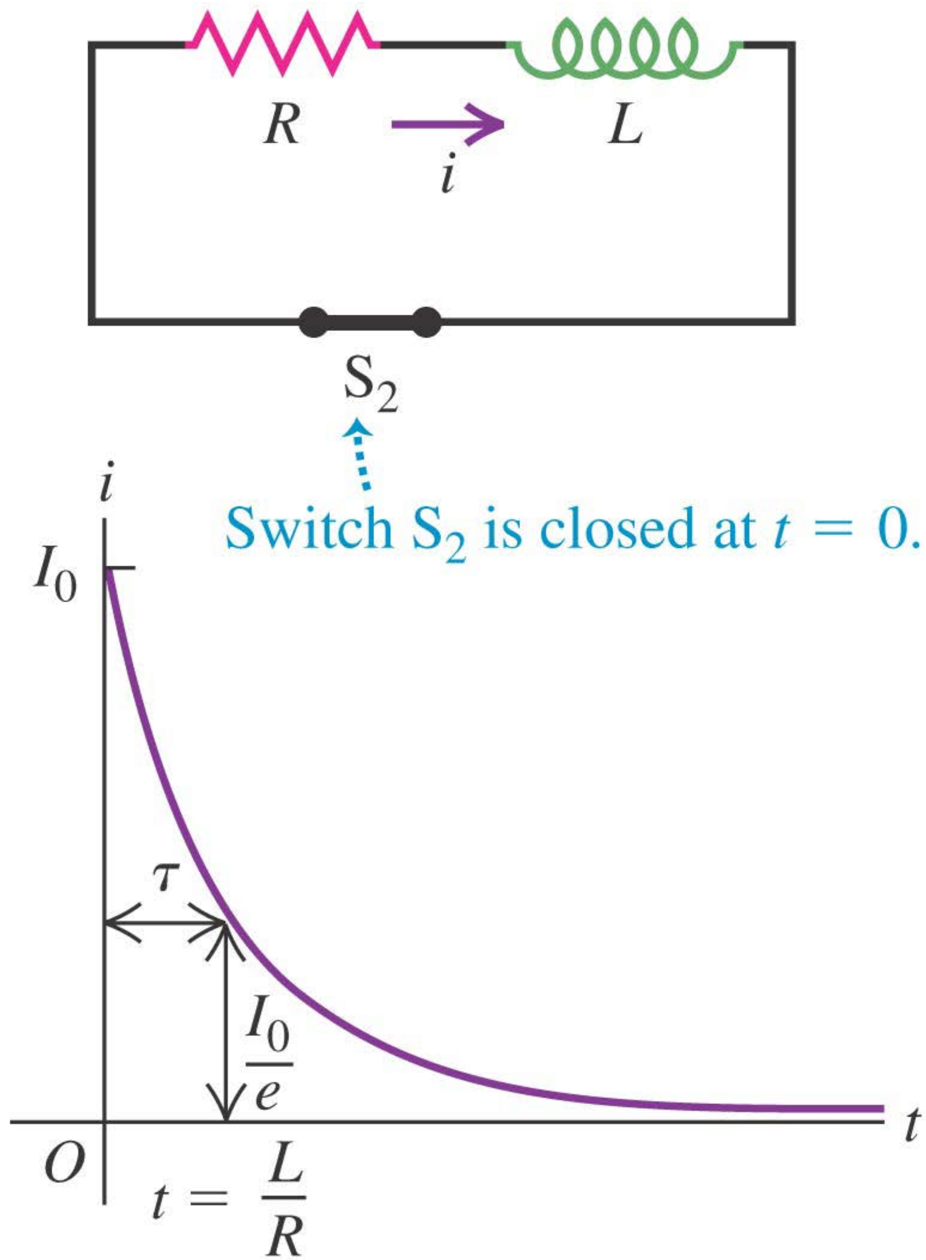
- Follow the text analysis of current growth in an *R-L* circuit.
- The *time constant* for an *R-L* circuit is $\tau = L/R$.
- Figure 30.12 at the right shows a graph of the current as a function of time in an *R-L* circuit containing an emf source.
- Follow Example 30.6.





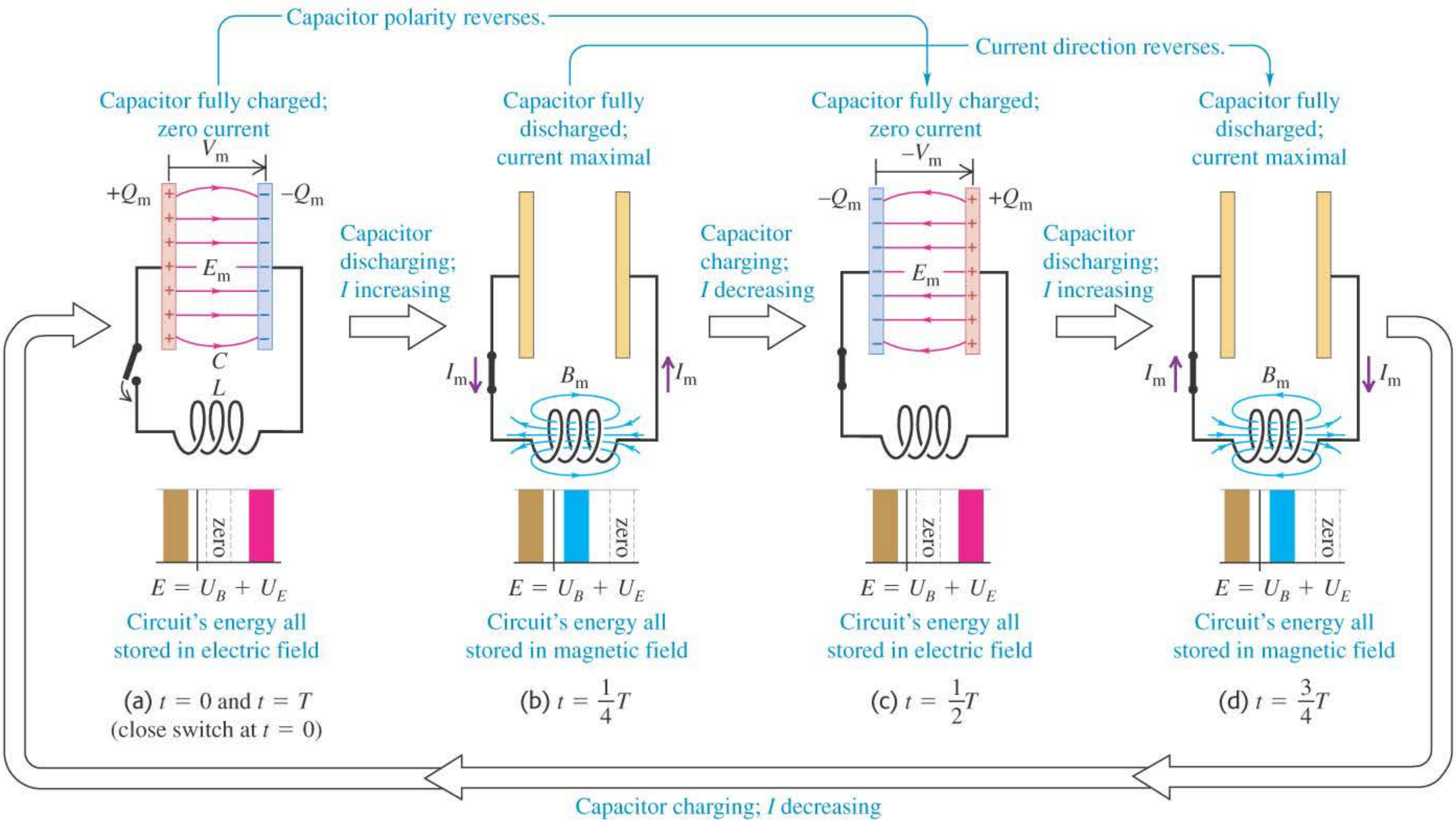
Current decay in an *R-L* circuit

- Read the text discussion of current decay in an *R-L* circuit.
- Figure 30.13 at the right shows a graph of the current versus time.
- Follow Example 30.7.



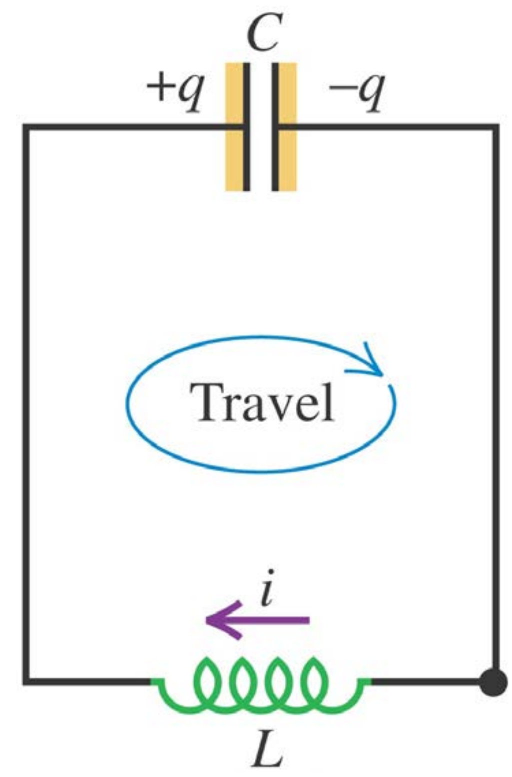
The *L-C* circuit

- An *L-C circuit* contains an inductor and a capacitor and is an *oscillating* circuit. See Figure 30.14 below.



Electrical oscillations in an *L-C* circuit

- Follow the text analysis of electrical oscillations and energy in an *L-C* circuit using Figure 30.15 at the right.



Electrical and mechanical oscillations

- Table 30.1 summarizes the analogies between SHM and *L-C* circuit oscillations.
- Follow Example 30.8.
- Follow Example 30.9.

Table 30.1 Oscillation of a Mass-Spring System Compared with Electrical Oscillation in an *L-C* Circuit

Mass-Spring System

Kinetic energy $= \frac{1}{2}mv_x^2$

Potential energy $= \frac{1}{2}kx^2$

$\frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$

$v_x = \pm\sqrt{k/m}\sqrt{A^2 - x^2}$

$v_x = dx/dt$

$\omega = \sqrt{\dfrac{k}{m}}$

$x = A\cos(\omega t + \phi)$

Inductor-Capacitor Circuit

Magnetic energy $= \frac{1}{2}Li^2$

Electric energy $= q^2/2C$

$\frac{1}{2}Li^2 + q^2/2C = Q^2/2C$

$i = \pm\sqrt{1/LC}\sqrt{Q^2 - q^2}$

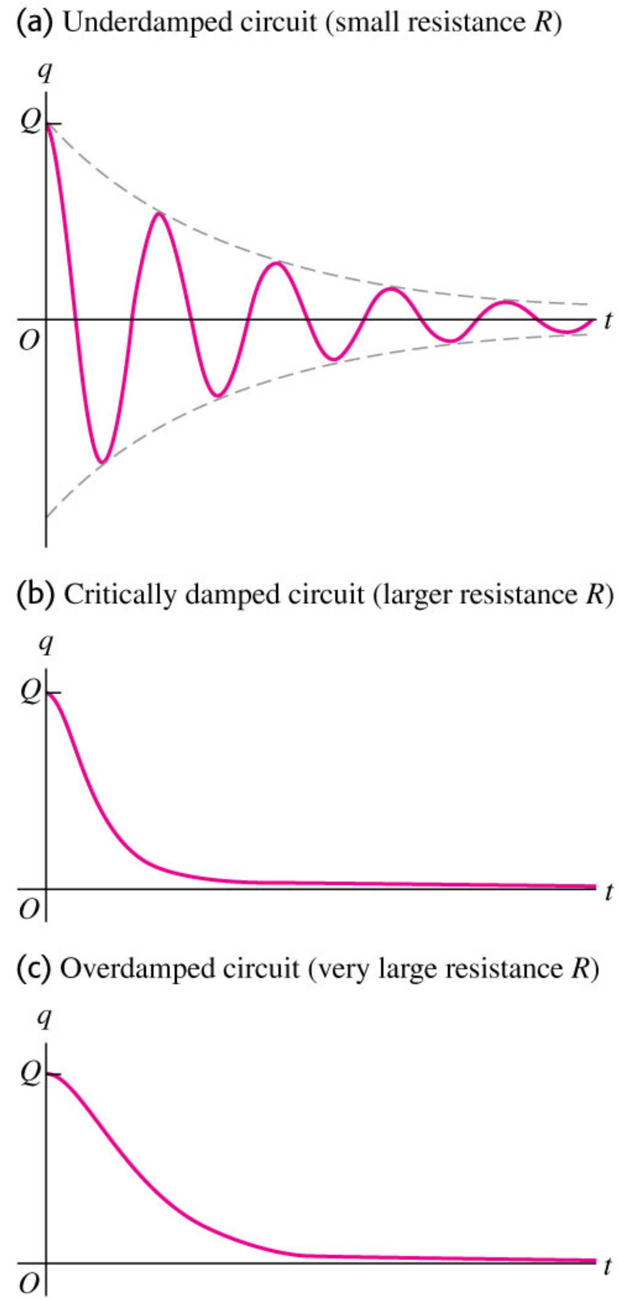
$i = dq/dt$

$\omega = \sqrt{\dfrac{1}{LC}}$

$q = Q\cos(\omega t + \phi)$

The *L-R-C* series circuit

- Follow the text analysis of an *L-R-C* circuit.
- An *L-R-C* circuit exhibits *damped harmonic motion* if the resistance is not too large. (See graphs in Figure 30.16 at the right.)
- Follow Example 30.10.



Maxwell's Equations To Date

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{e\_enc}}{\epsilon_o}$$

Gauss' Law

$$\oint \vec{B} \cdot d\vec{A} = 0$$

"No Name Law"

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I_{e\_enc} - \epsilon_o \mu_o \frac{\delta}{\delta t} \int \vec{E} \cdot d\vec{A}$$

Ampere's Law
w/ Maxwell's Correction

$$\oint \vec{E} \cdot d\vec{\ell} = -\frac{\delta}{\delta t} \int \vec{B} \cdot d\vec{A}$$

Faraday's Law

But no magnetic monopoles have been found!
So no magnetic current!