

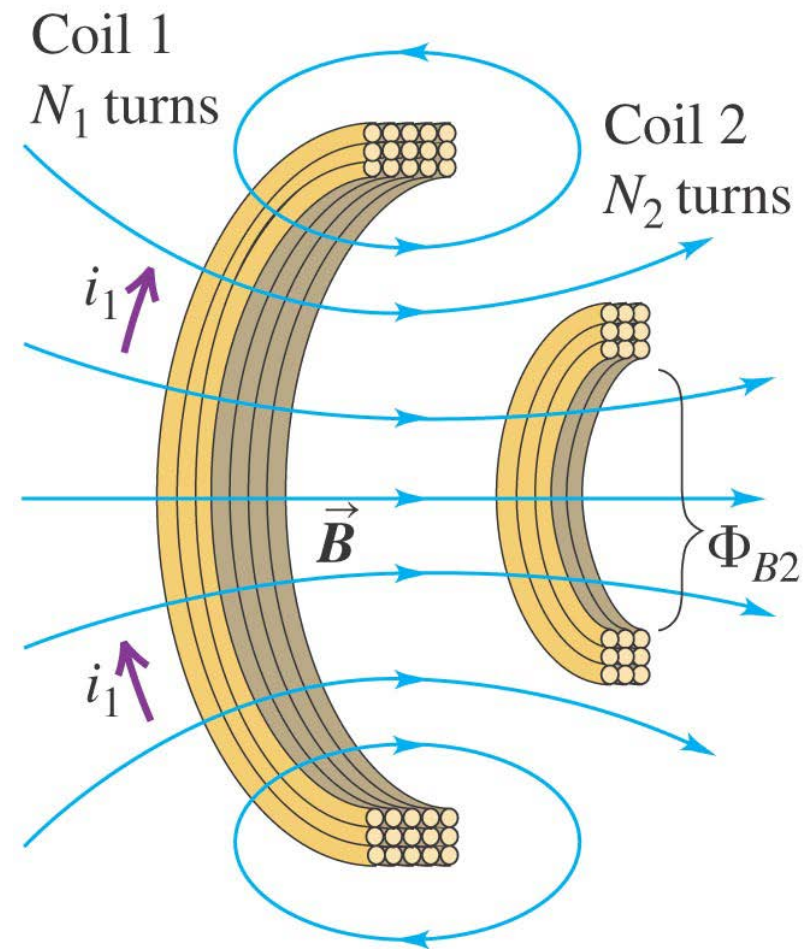
PHYS121H - Lecture 12: Inductance and RLC Circuits

- 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.

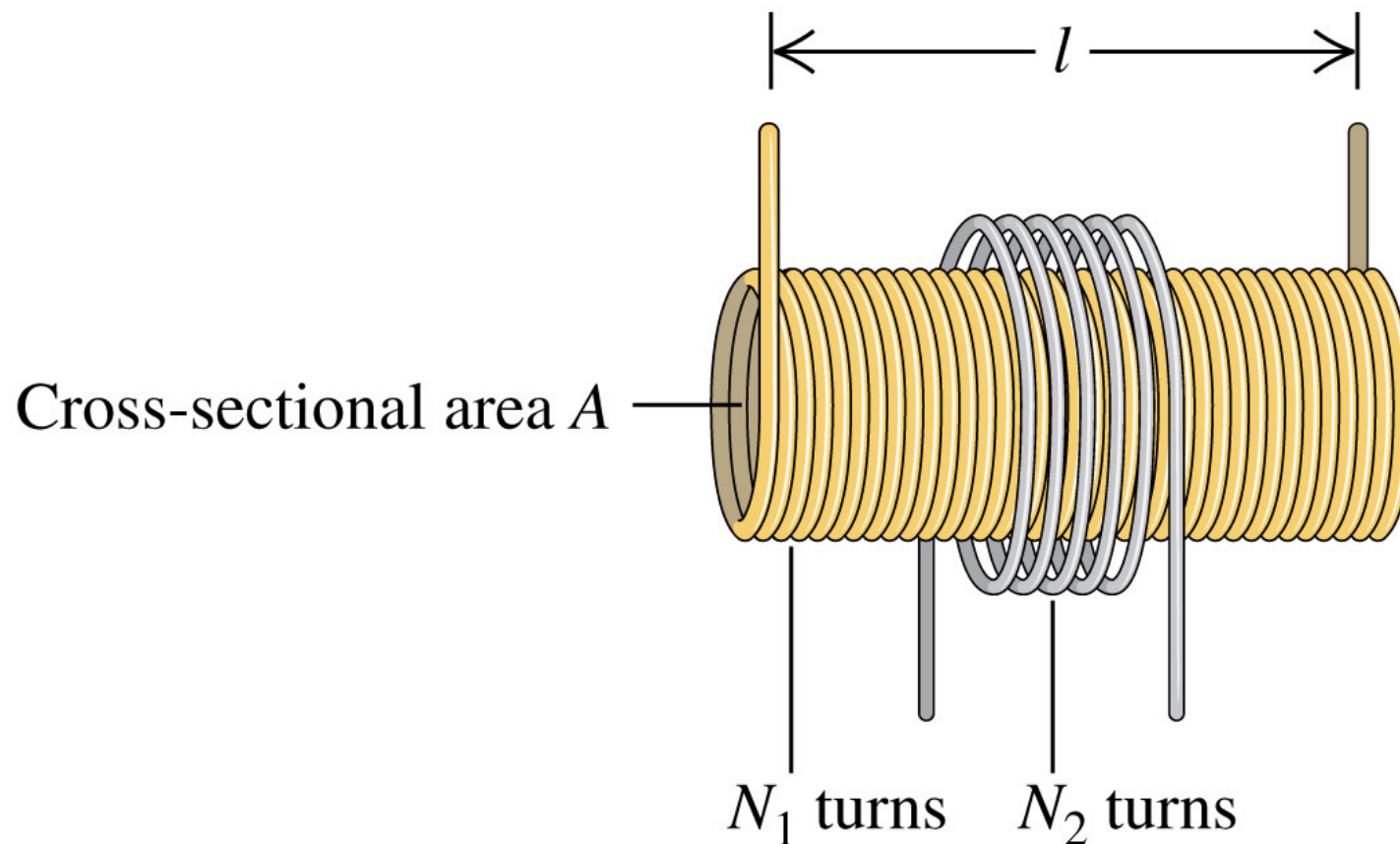
Mutual inductance: If the current in coil 1 is changing, the changing flux through coil 2 induces an emf in coil 2.





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.

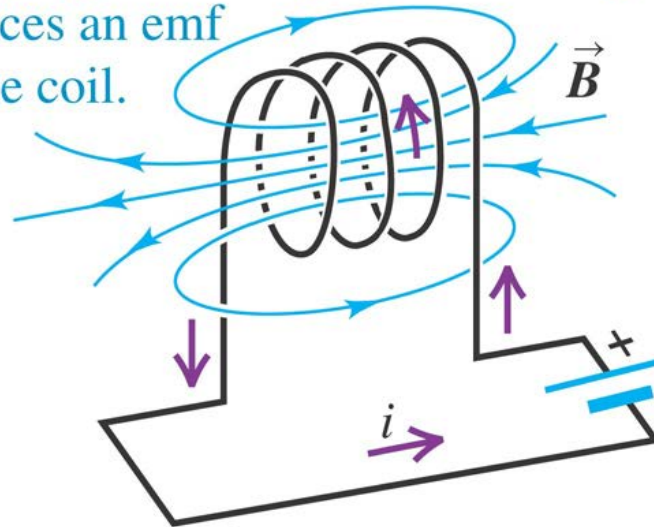




Self-inductance

- *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.

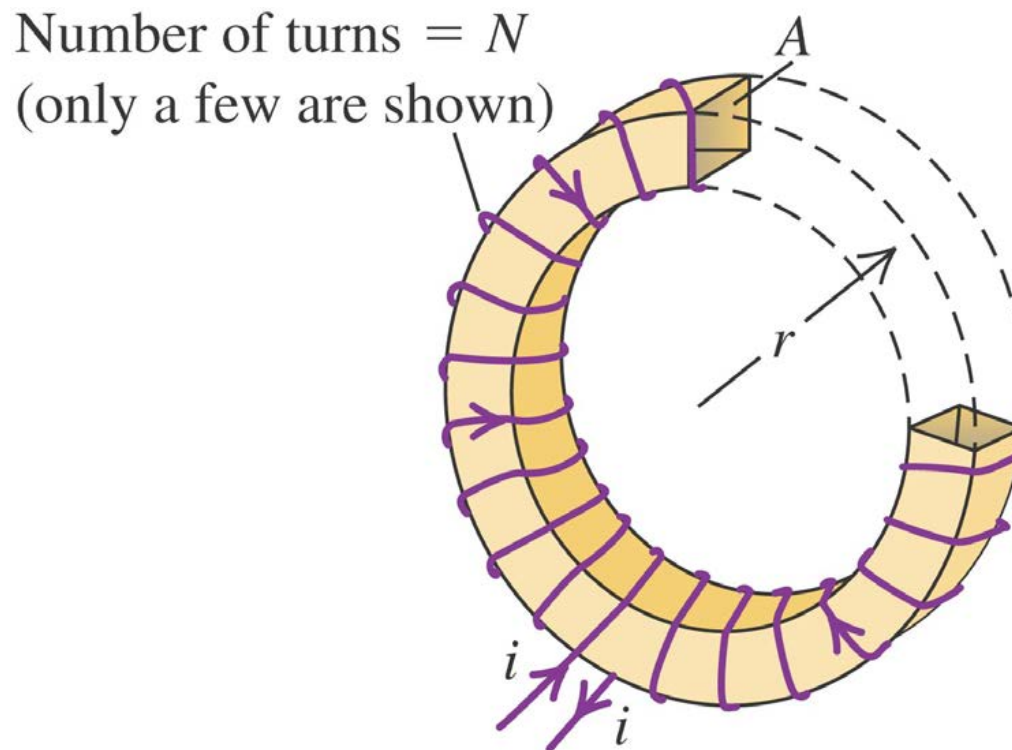
Self-inductance: If the current i in the coil is changing, the changing flux through the coil induces an emf in the coil.





Calculating self-inductance and self-induced emf

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

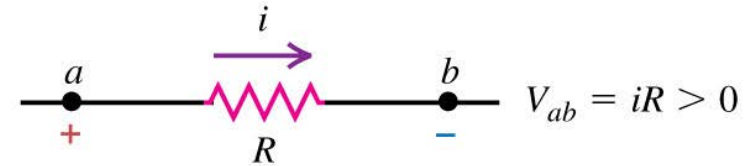




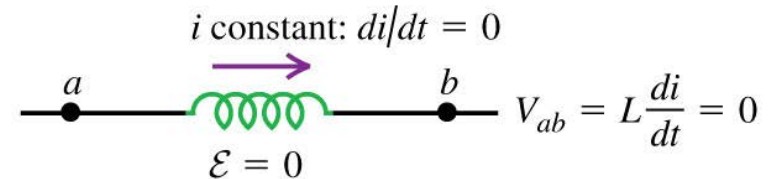
Potential across an inductor

- 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.

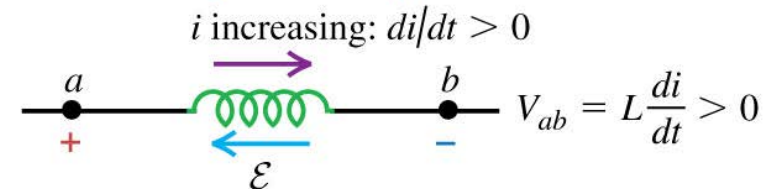
(a) Resistor with current i flowing from a to b : potential drops from a to b .



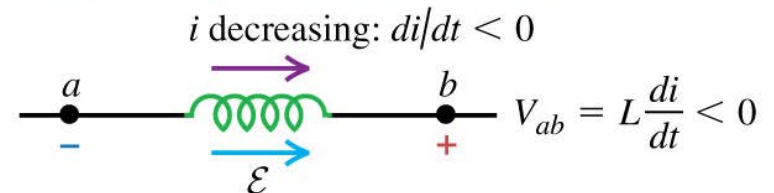
(b) Inductor with *constant* current i flowing from a to b : no potential difference.



(c) Inductor with *increasing* current i flowing from a to b : potential drops from a to b .



(d) Inductor with *decreasing* current i flowing from a to b : potential increases from a to b .

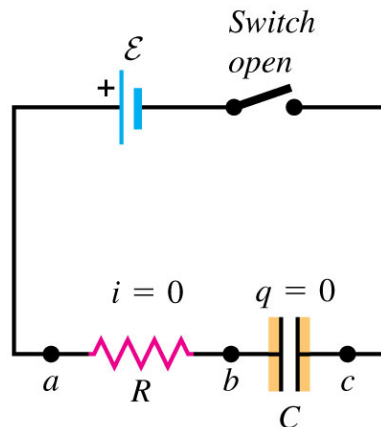




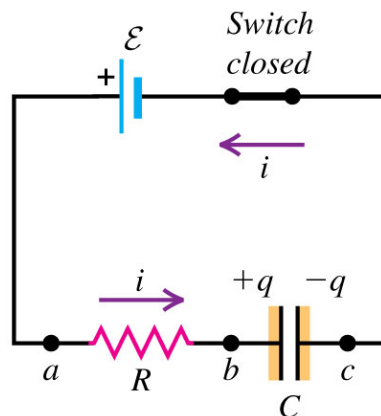
Charging a capacitor

- 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

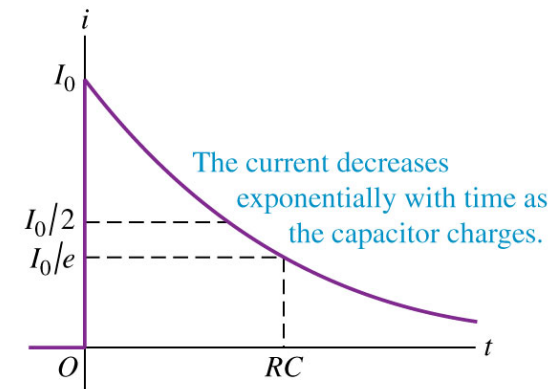


(b) Charging the capacitor

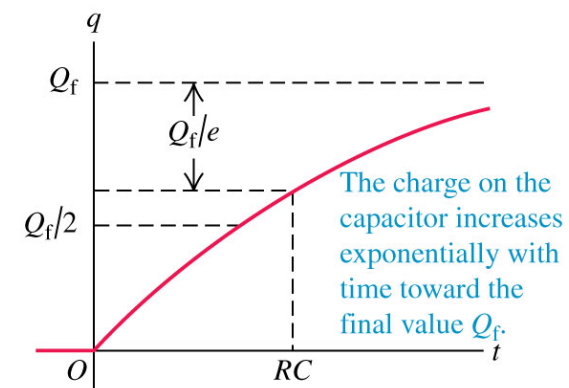


When the switch is closed, the charge on the capacitor increases over time while the current decreases.

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



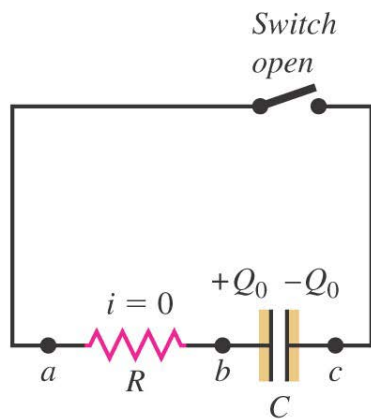
(b) Graph of capacitor charge versus time for a charging capacitor



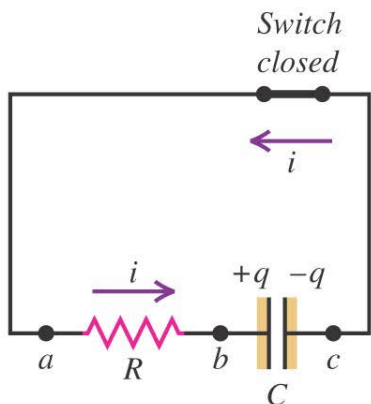
Discharging a capacitor

- 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.

(a) Capacitor initially charged

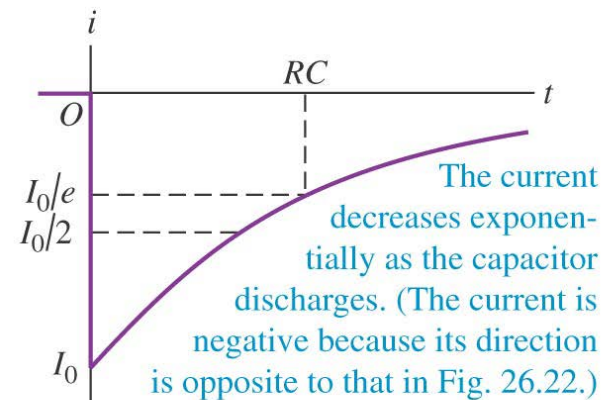


(b) Discharging the capacitor

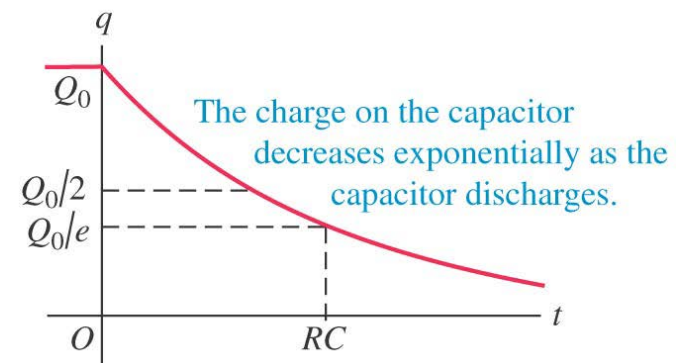


When the switch is closed, the charge on the capacitor and the current both decrease over time.

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



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

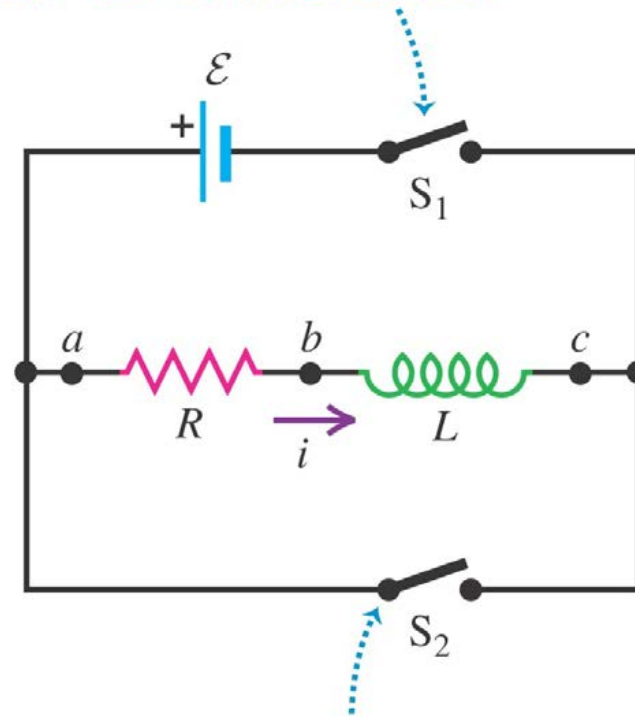




The R - L circuit

- 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.

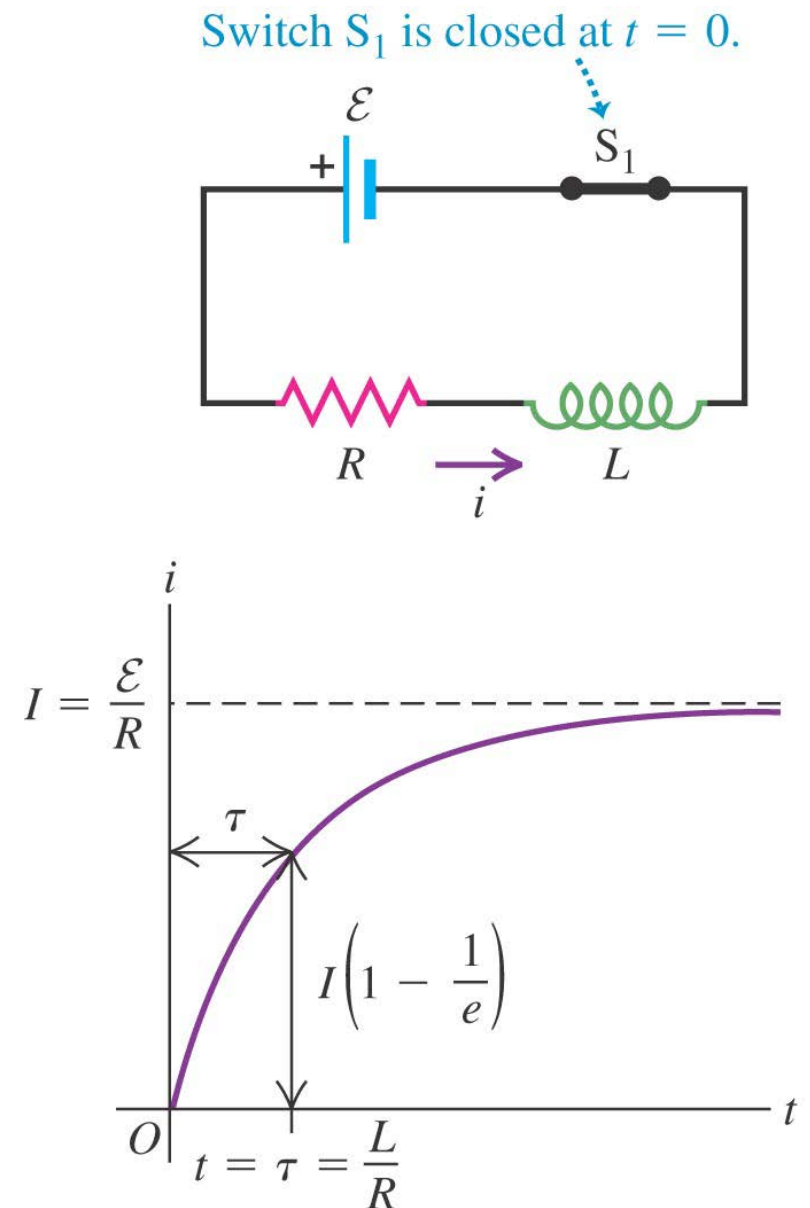
Closing switch S_1 connects the R - L combination in series with a source of emf \mathcal{E} .



Closing switch S_2 while opening switch S_1 disconnects the combination from the source.

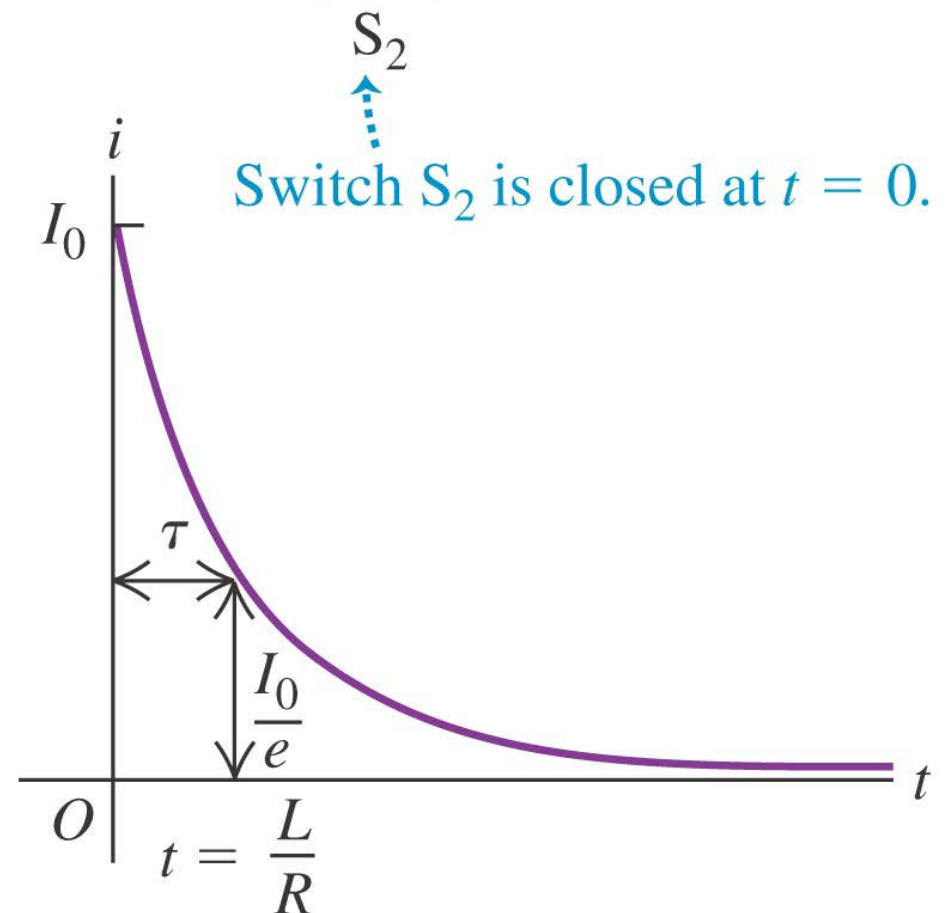
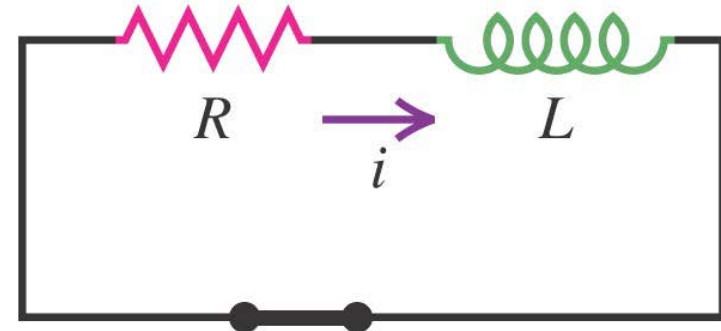
Current growth in an R - L circuit

- 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.



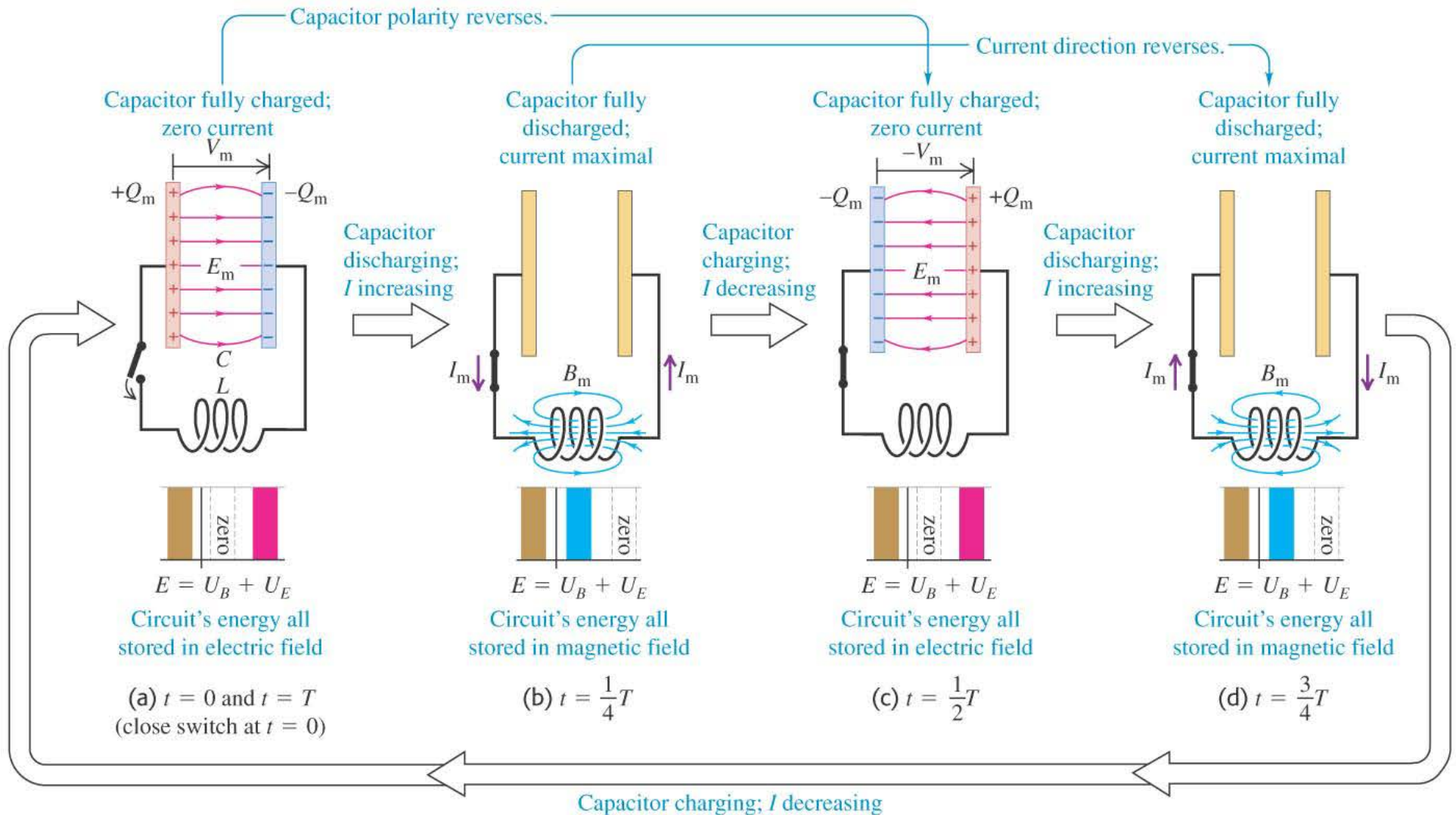
Current decay in an R - L circuit

- 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.



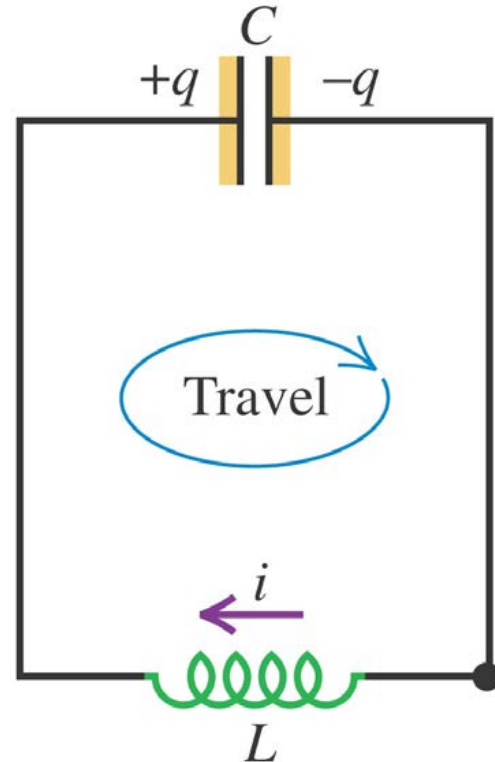
The L - C circuit

- 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

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

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

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

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

$$v_x = dx/dt$$

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

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

Inductor-Capacitor Circuit

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

$$\text{Electric energy} = q^2/2C$$

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

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

$$i = dq/dt$$

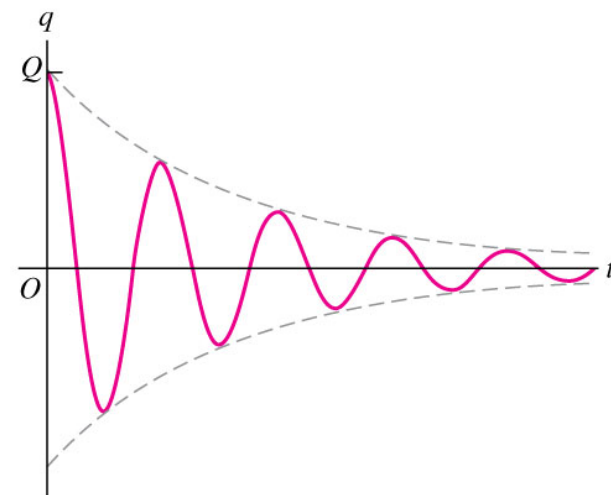
$$\omega = \sqrt{\frac{1}{LC}}$$

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

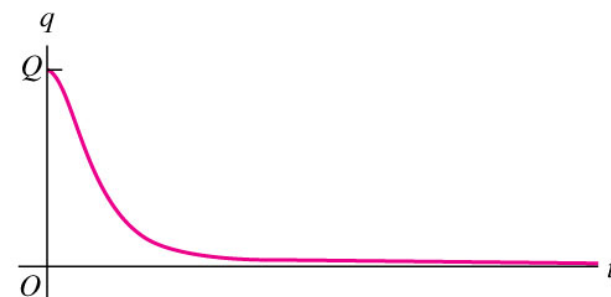
The L - R - C series circuit

- 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.

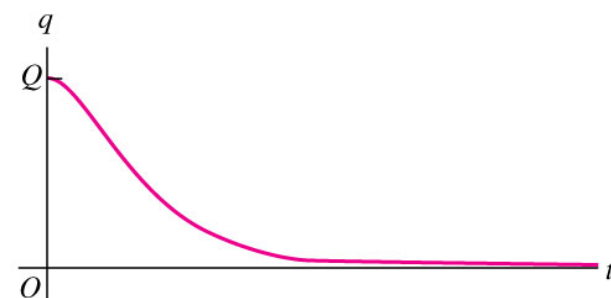
(a) Underdamped circuit (small resistance R)



(b) Critically damped circuit (larger resistance R)



(c) Overdamped circuit (very large resistance R)





Maxwell's Equations To Date

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{e_enc}}{\epsilon_0}$$

Gauss' Law

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

"No Name Law"

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{e_enc} - \epsilon_0 \mu_0 \frac{\delta}{\delta t} \int \vec{E} \cdot d\vec{A}$$

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!