Chapter 30

Inductance

PowerPoint® Lectures for
University Physics, Thirteenth Edition
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Goals for Chapter 30

- To learn how current in one coil can induce an emf in another unconnected coil
- To relate the induced emf to the rate of change of the current
- To calculate the energy in a magnetic field
- To analyze circuits containing resistors and inductors
- To describe electrical oscillations in circuits and why the oscillations decay

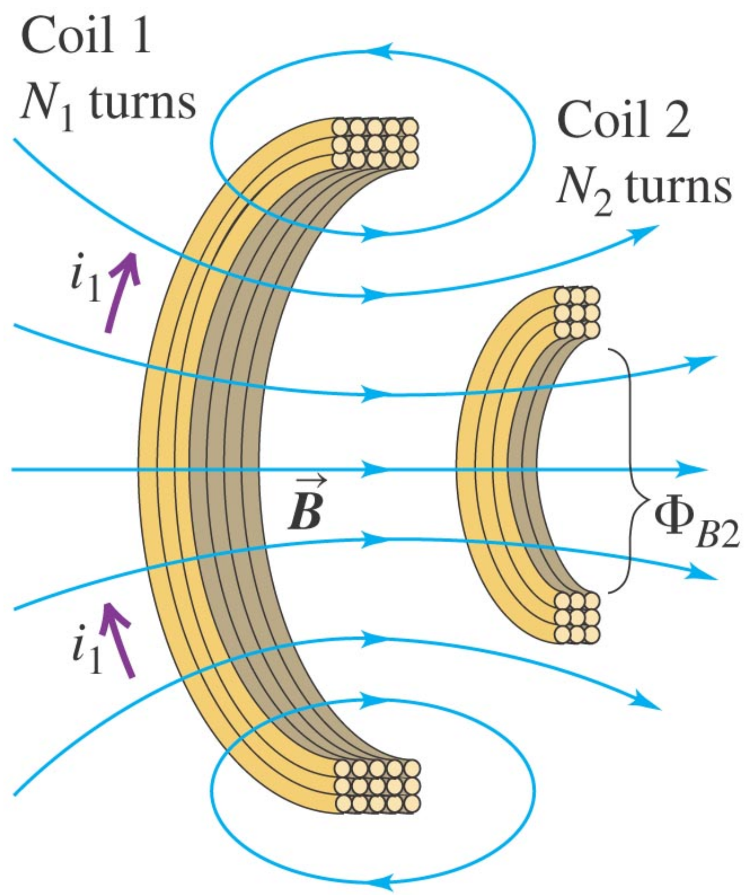
Introduction

- How does a coil induce a current in a neighboring coil.
- A sensor triggers the traffic light to change when a car arrives at an intersection. How does it do this?
- Why does a coil of metal behave very differently from a straight wire of the same metal?
- We'll learn how circuits can be coupled without being connected together.

Mutual inductance

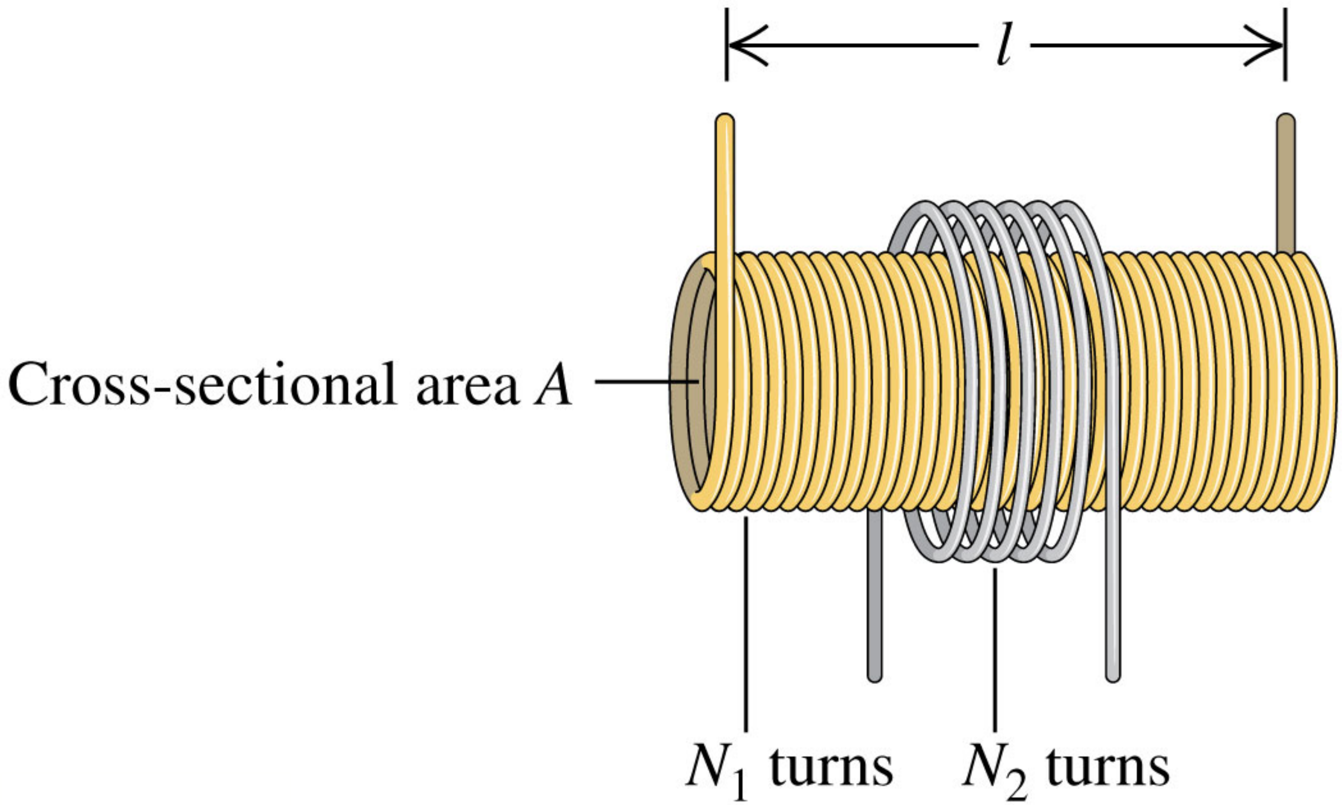
- *Mutual inductance*: A changing current in one coil induces a current in a neighboring coil. See Figure 30.1 at the right.
- Follow the discussion of mutual inductance in the text.

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



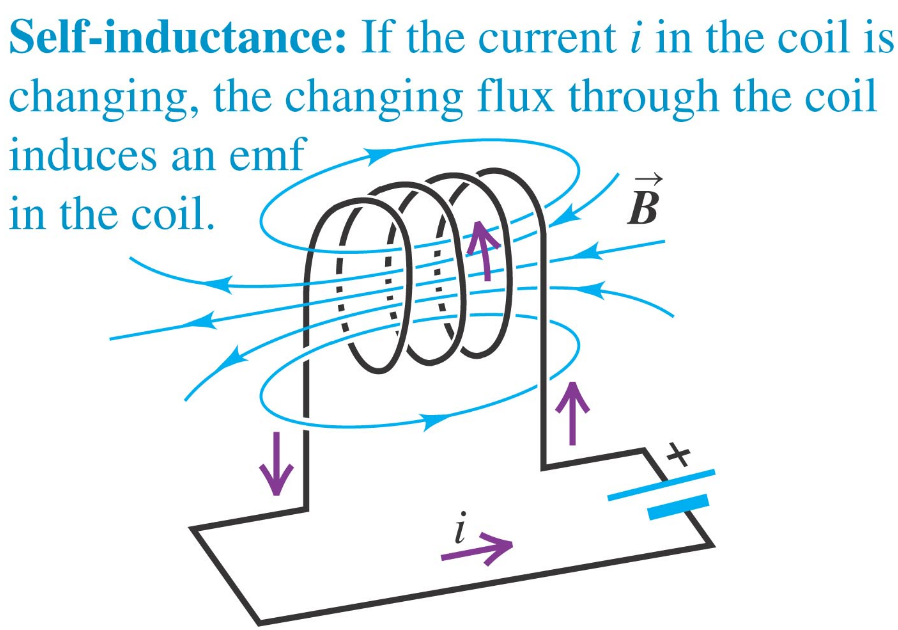
Mutual inductance examples

- 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.



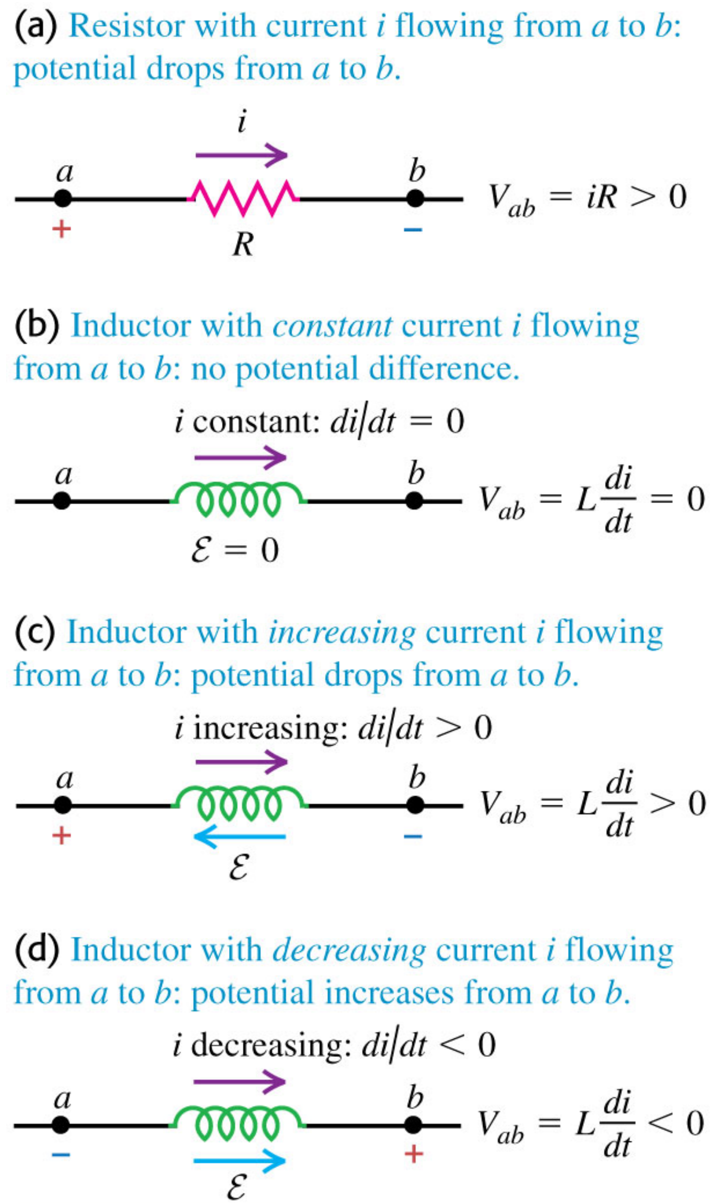
Self-inductance

- *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.



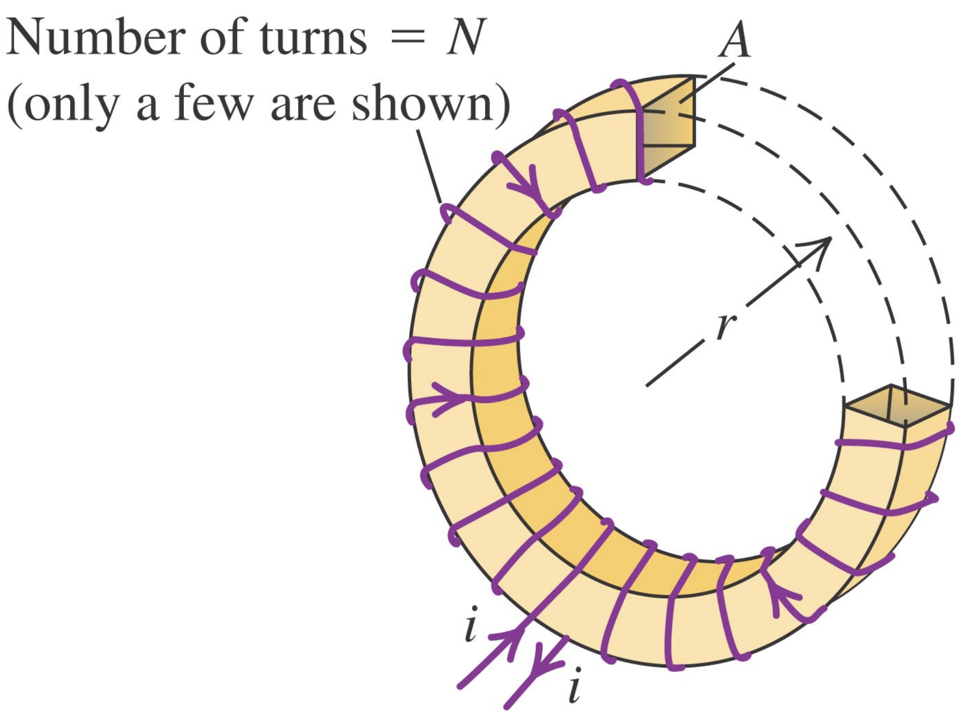
Potential across an inductor

- 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.



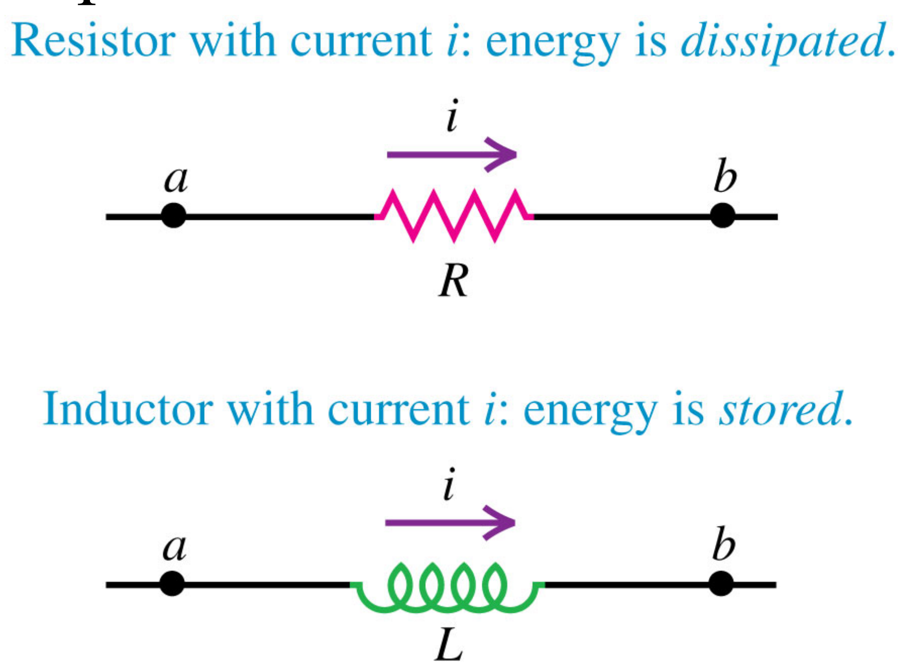
Calculating self-inductance and self-induced emf

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



Magnetic field energy

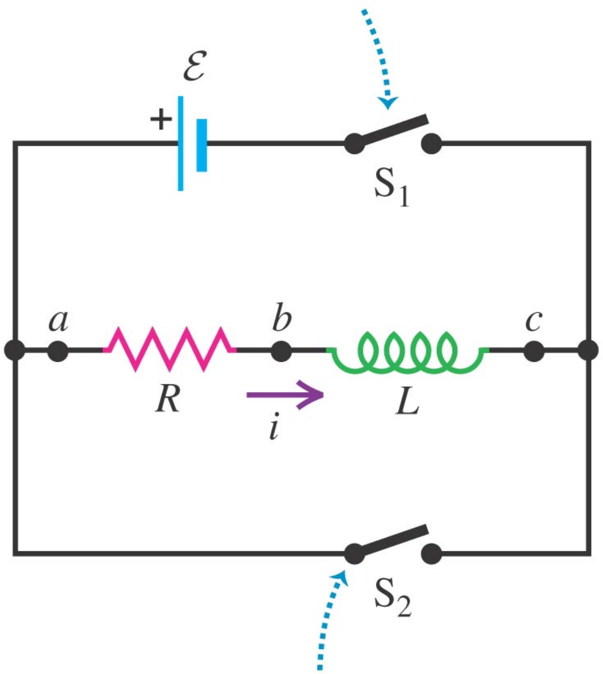
- The energy stored in an inductor is $U = 1/2\ LI^2$. See Figure 30.9 below.
- The energy density in a magnetic field is $u = B^2/2\mu_0$ (in vacuum) and $u = B^2/2\mu$ (in a material).
- Follow Example 30.5.



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.

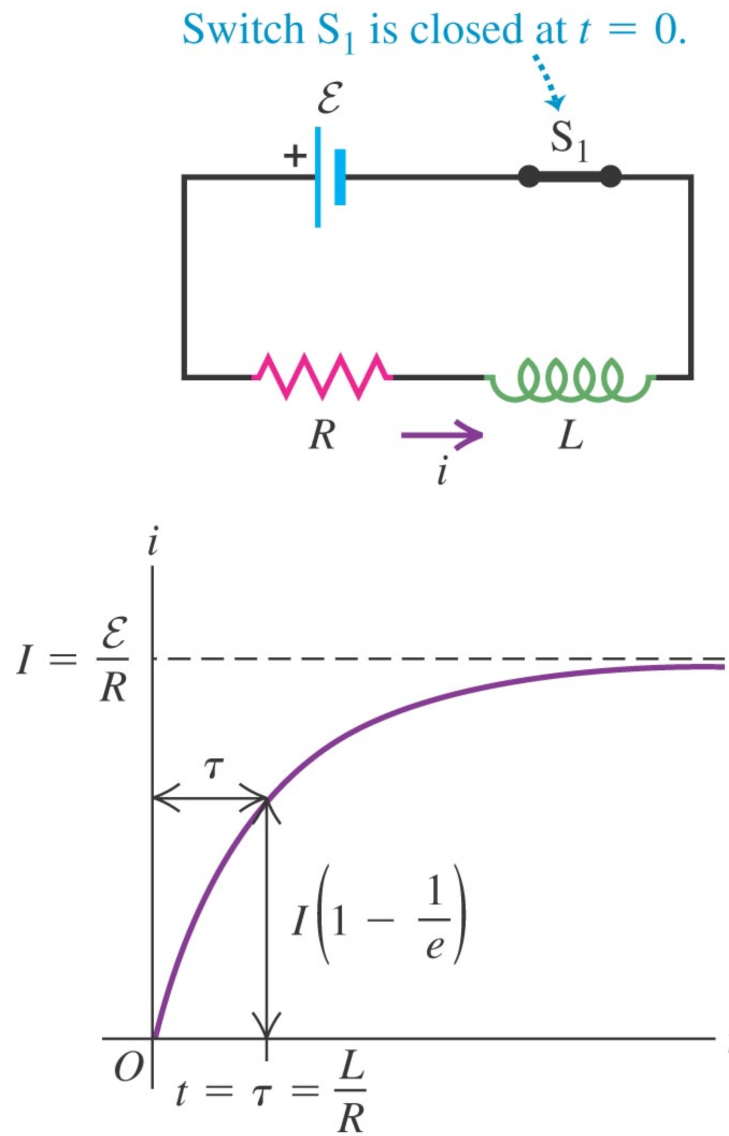
Closing switch S_1 connects the *R-L* combination in series with a source of emf $\mathcal{E}$.



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

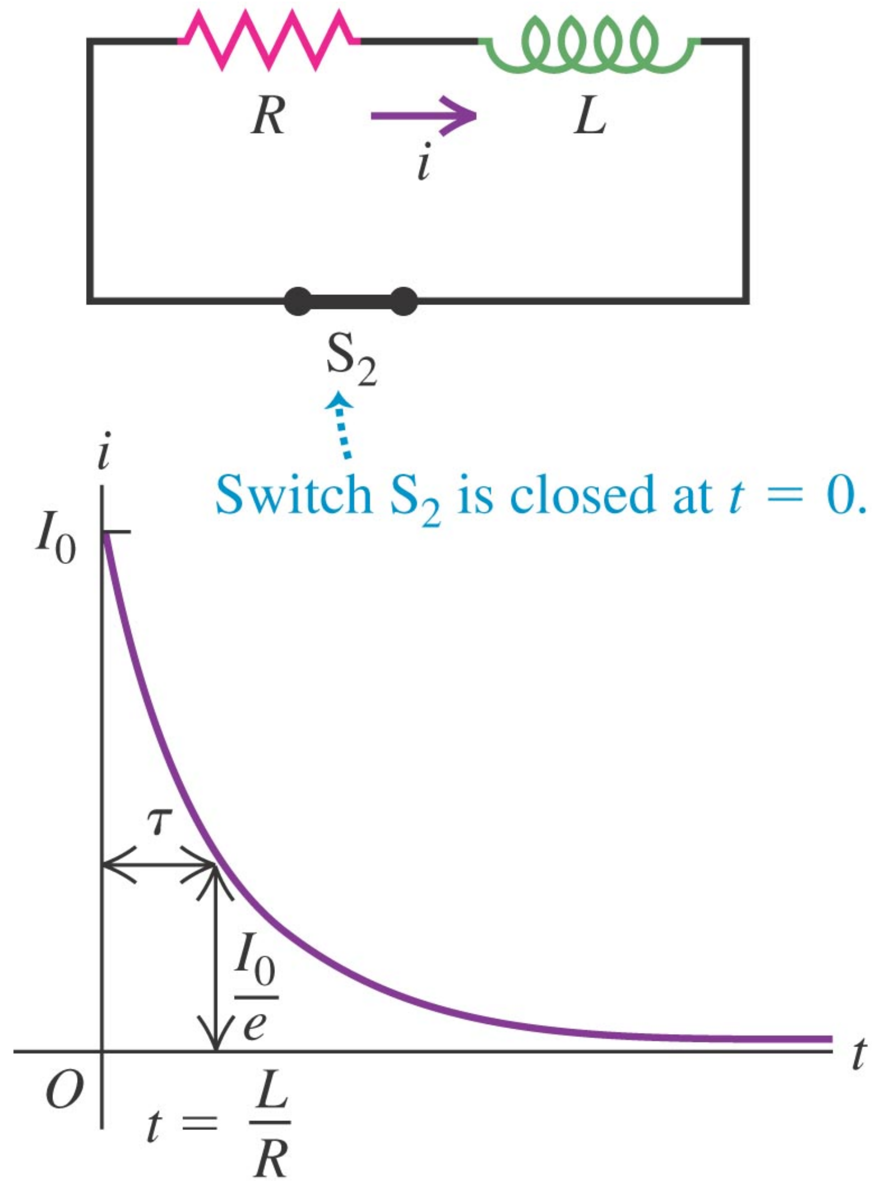
Current growth in an *R-L* circuit

- 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.



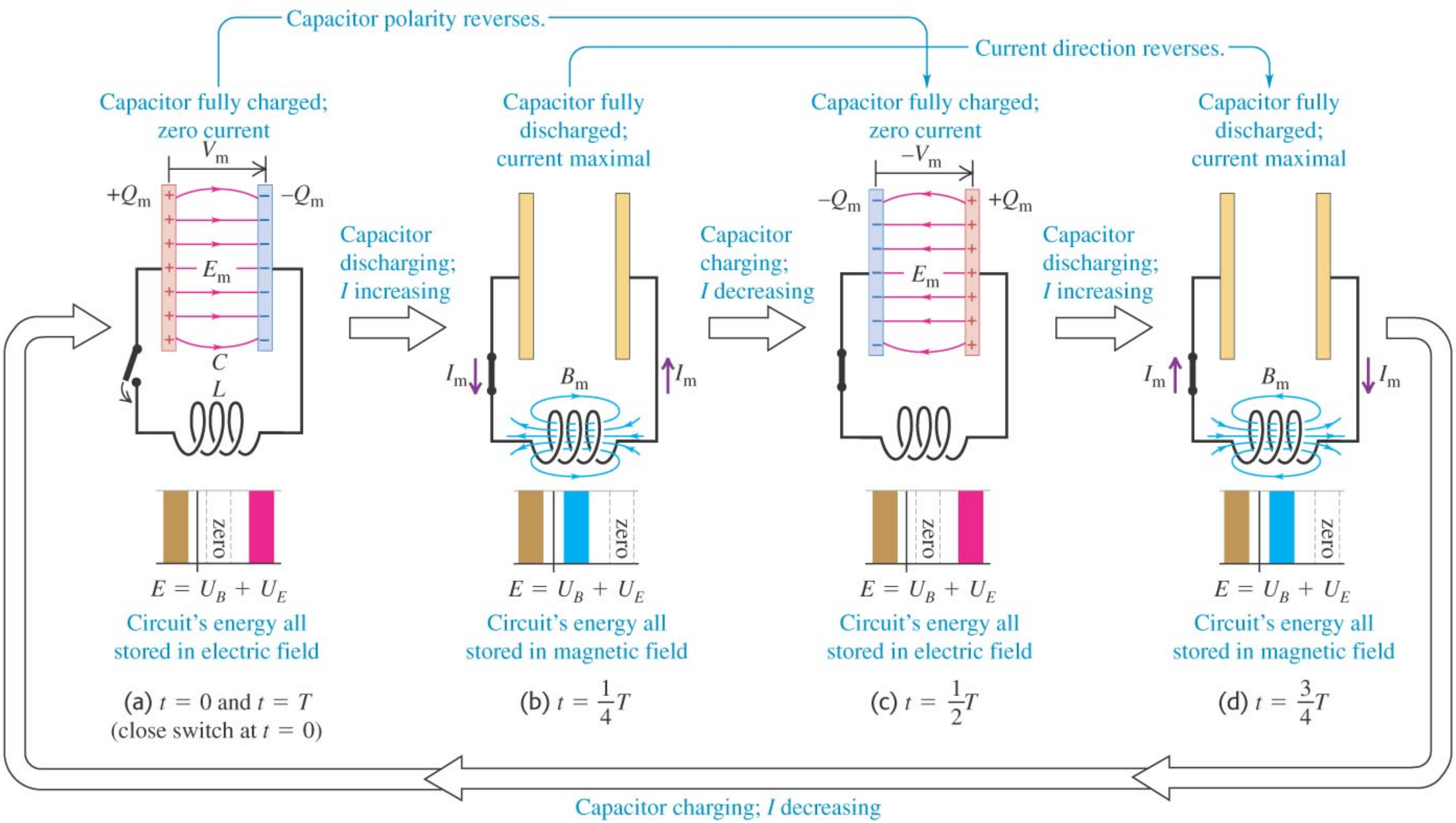
Current decay in an *R-L* circuit

- 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.



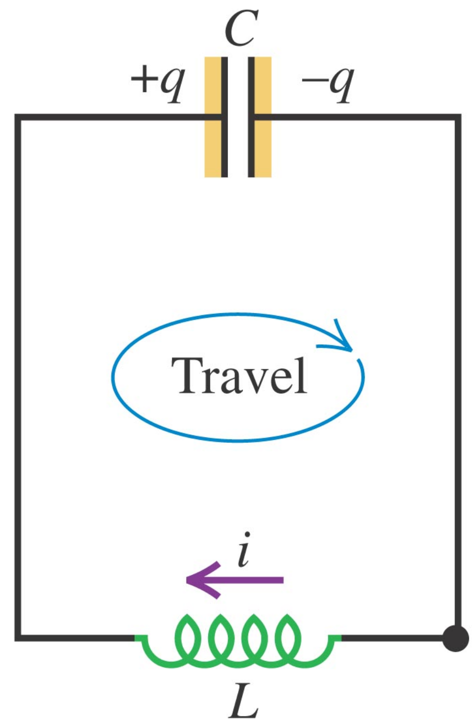
The *L-C* circuit

- 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

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 $= q^2/2C$

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

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

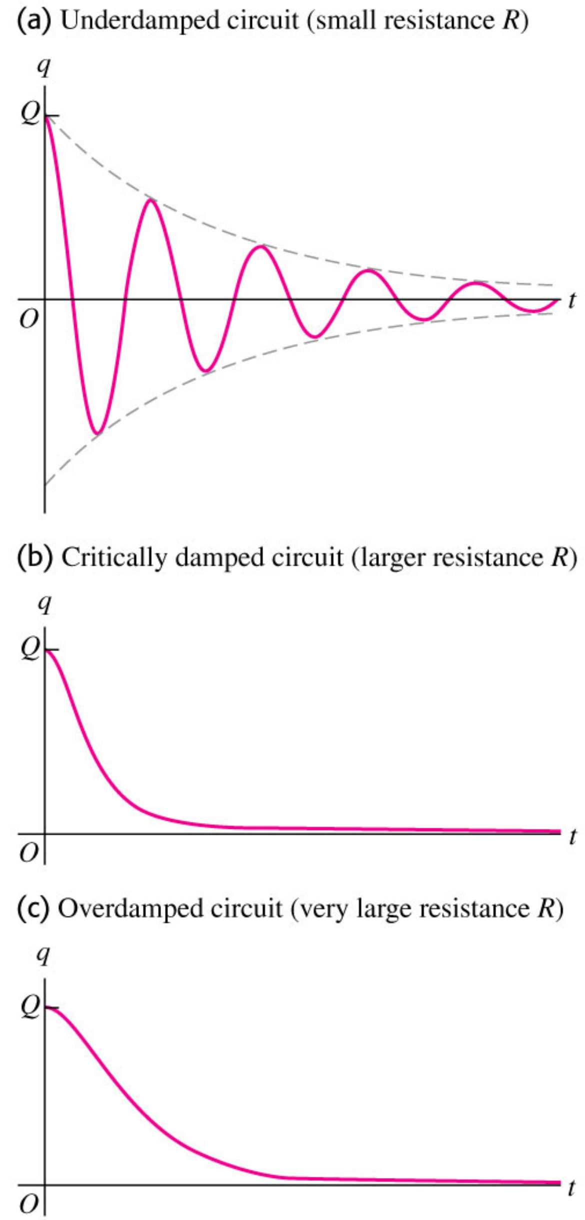
$i = dq/dt$

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

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

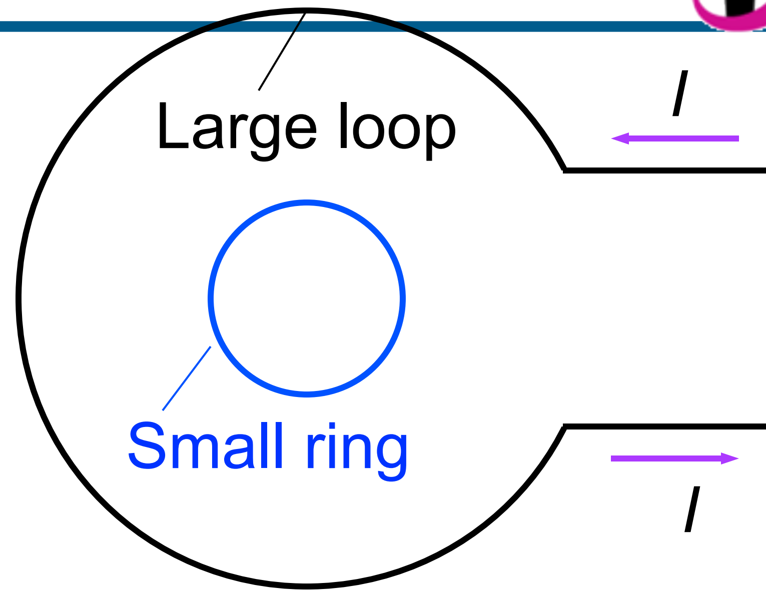
The *L-R-C* series circuit

- 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.



Q30.1

A small, circular ring of wire (shown in blue) is inside a larger loop of wire that carries a current *I* as shown. The small ring and the larger loop both lie in the same plane. If *I* increases, the current that flows in the small ring



A. is clockwise and caused by self-inductance.

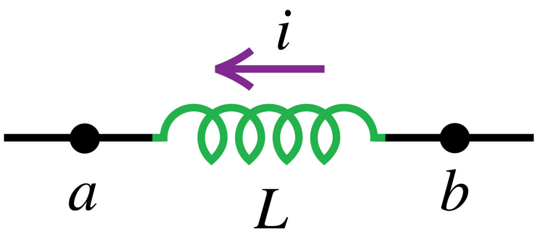
B. is counterclockwise and caused by self-inductance.

C. is clockwise and caused by mutual inductance.

D. is counterclockwise and caused by mutual inductance.

Q30.2

A current *i* flows through an inductor *L* in the direction from point *b* toward point *a*. There is zero resistance in the wires of the inductor. If the current is *decreasing*,



A. the potential is greater at point *a* than at point *b.*

B. the potential is less at point *a* than at point *b.*

C. The answer depends on the magnitude of *di/dt* compared to the magnitude of *i.*

D. The answer depends on the value of the inductance *L.*

E. both C. and D. are correct.

Q30.3

A steady current flows through an inductor. If the current is doubled while the inductance remains constant, the amount of energy stored in the inductor

A. increases by a factor of $\sqrt{2}$.

B. increases by a factor of 2.

C. increases by a factor of 4.

D. increases by a factor that depends on the geometry of the inductor.

E. none of the above

Q30.4

An inductance L and a resistance R are connected to a source of emf as shown. When switch S_1 is closed, a current begins to flow. The *final* value of the current is

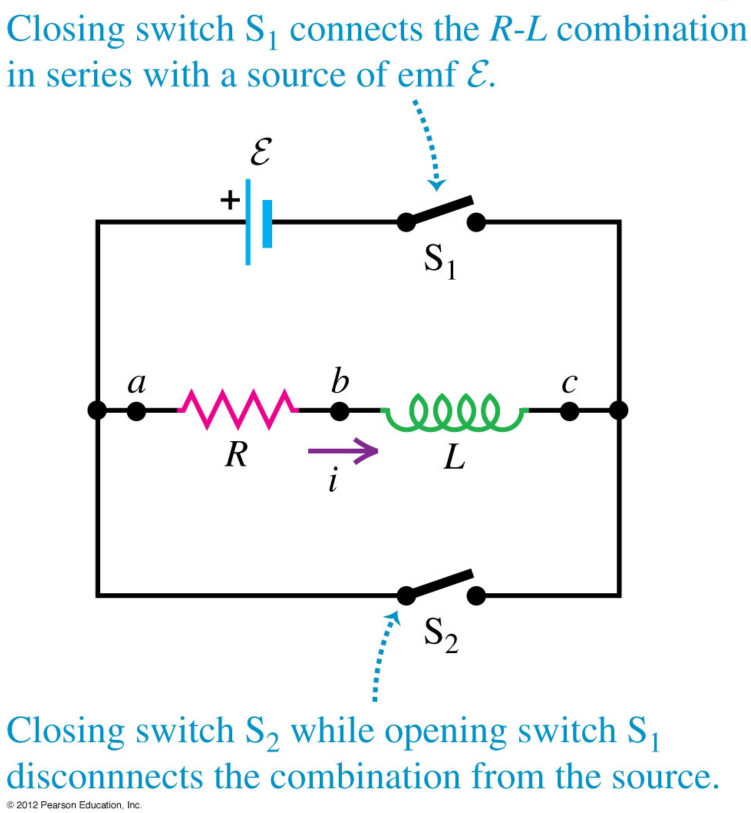
A. directly proportional to RL.

B. directly proportional to R/L.

C. directly proportional to L/R.

D. directly proportional to $1/(RL)$.

E. independent of L.



Q30.5

An inductance L and a resistance R are connected to a source of emf as shown. When switch S_1 is closed, a current begins to flow. The *time* required for the current to reach one-half its final value is

A. directly proportional to RL.

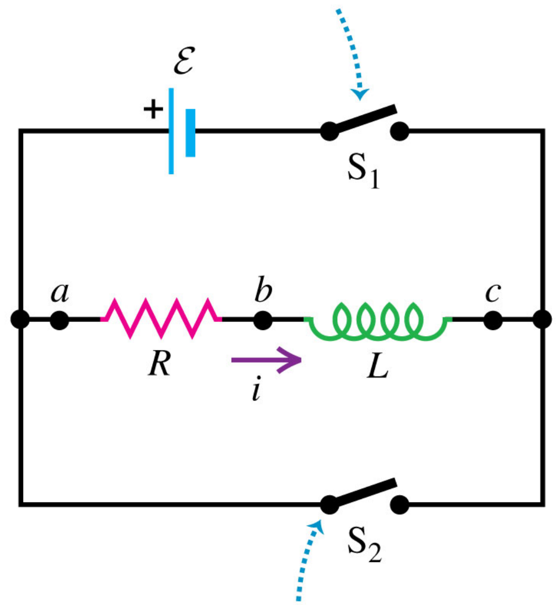
B. directly proportional to R/L.

C. directly proportional to L/R.

D. directly proportional to $1/(RL)$.

E. independent of L.

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 disconnnects the combination from the source.

Q30.6

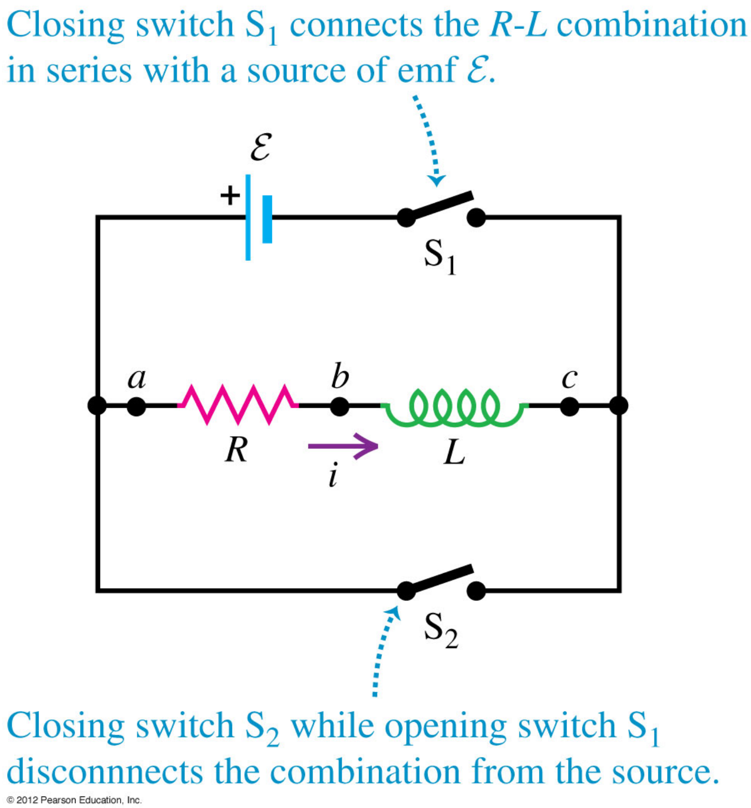
An inductance L and a resistance R are connected to a source of emf as shown. Initially switch S_1 is closed, switch S_2 is open, and current flows through L and R. When S_2 is closed, the *rate* at which this current decreases

A. remains constant.

B. increases with time.

C. decreases with time.

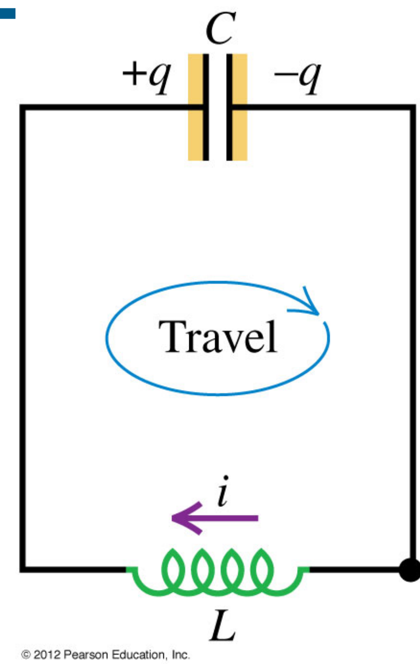
D. not enough information given to decide



Q30.7

An inductor (inductance *L*) and a capacitor (capacitance *C*) are connected as shown.

If the values of both *L* and *C* are doubled, what happens to the *time* required for the capacitor charge to oscillate through a complete cycle?



A. It becomes 4 times longer.

B. It becomes twice as long.

C. It is unchanged.

D. It becomes 1/2 as long.

E. It becomes 1/4 as long.

Q30.8

An inductor (inductance L) and a capacitor (capacitance C) are connected as shown. The value of the capacitor charge q oscillates between positive and negative values. At any instant, the potential difference between the capacitor plates is

A. proportional to q.

B. proportional to dq/dt.

C. proportional to d^2q/dt^2.

D. both A. and C.

E. all of A., B., and C.