Alternating-Current Circuits

BY
Dr. Neeta Singh
Assistant Professor

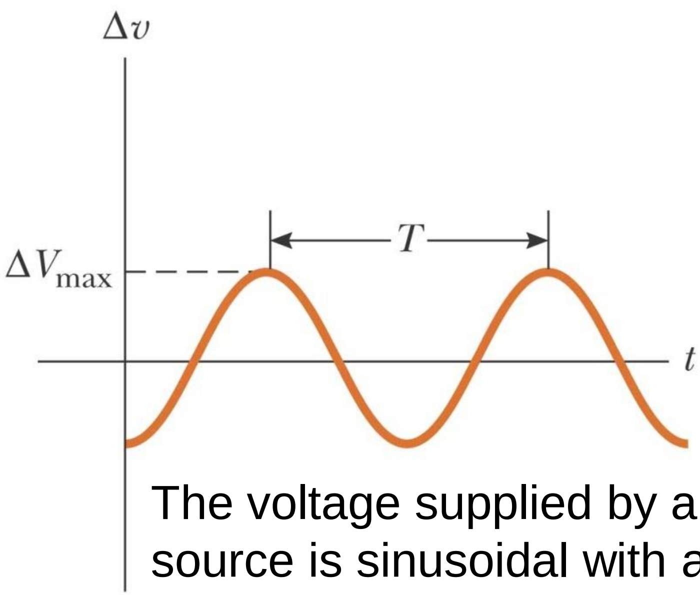
AC SOURCES AND PHASORS

.. the basic principle of the ac generator is a direct consequence of Faraday's law of induction. When a conducting loop is rotated in a magnetic field at constant angular frequency ω , a sinusoidal voltage (emf) is induced in the loop. This instantaneous voltage Δ*v is*

$$\Delta v = \Delta V_{\max} \sin \omega t$$

where ΔV_{max} *is the maximum output voltage of the ac generator, or the voltage* amplitude, the angular frequency is

$$\omega = 2\pi f = \frac{2\pi}{T}$$



The voltage supplied by an AC source is sinusoidal with a period *T*.

where *f is the frequency of the generator (the voltage source) and T is the period.*

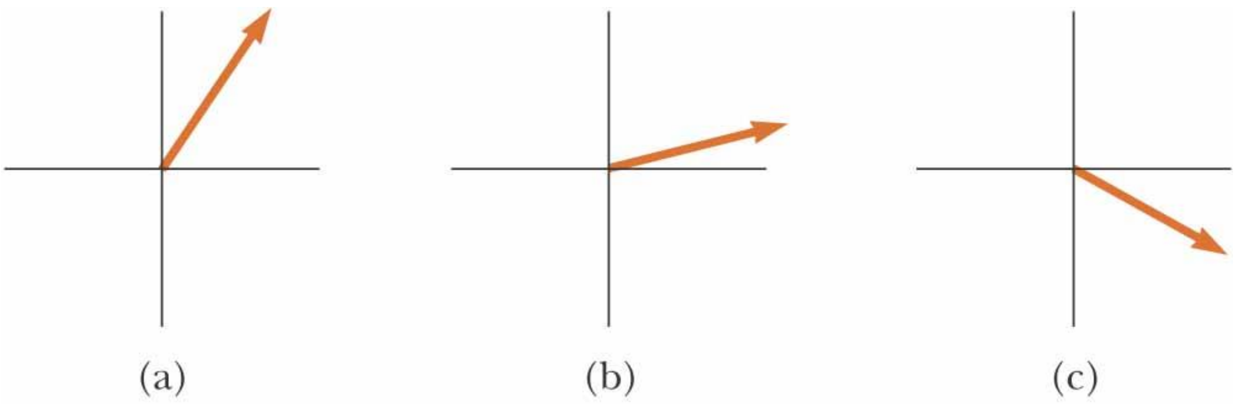
Commercial electric power plants in the United States use a frequency of 60 Hz, which corresponds to an angular frequency of 377 rad/s.

➢To simplify our analysis of circuits containing two or more elements, we use graphical constructions called ***phasor diagrams**.*

➢*In these constructions, alternating (sinusoidal)* quantities, such as current and voltage, are represented by rotating vectors called **phasors**.

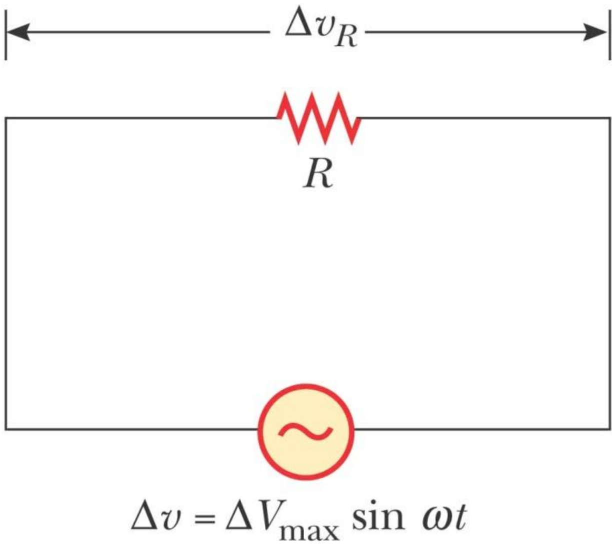
➢The length of the phasor represents the amplitude (maximum value) of the quantity, and the projection of the phasor onto the vertical axis represents the instantaneous value of the quantity.

➢As we shall see, a phasor diagram greatly simplifies matters when we must combine several sinusoidally varying currents or voltages that have different phases.



RESISTORS IN AN AC CIRCUIT

At any instant, the algebraic sum of the voltages around a closed loop in a circuit must be zero (Kirchhoff's loop rule).



$$\Delta v = \Delta v_R = \Delta V_{max} \sin \omega t$$

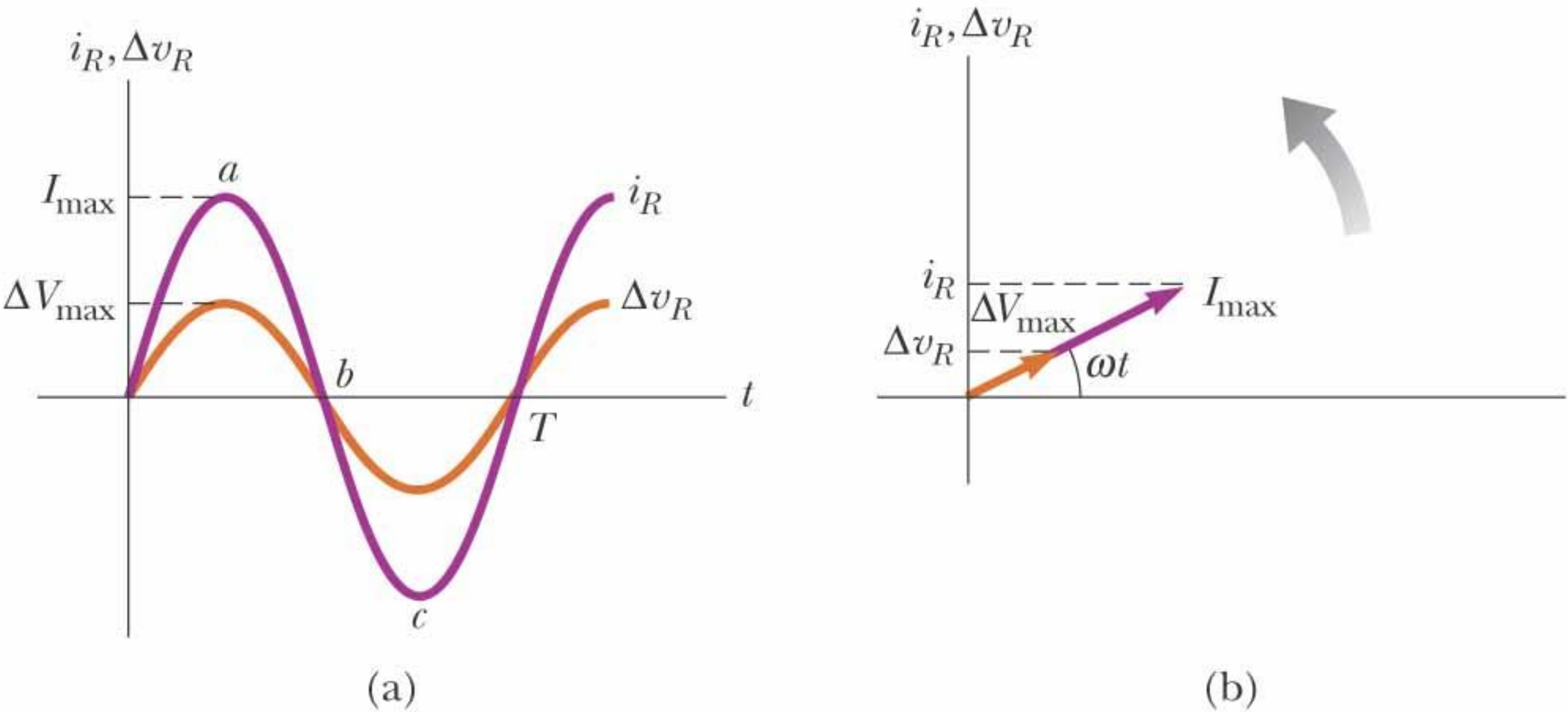
where Δv_R *is the instantaneous voltage across the resistor. Therefore, the* ***instantaneous* current** in the resistor is

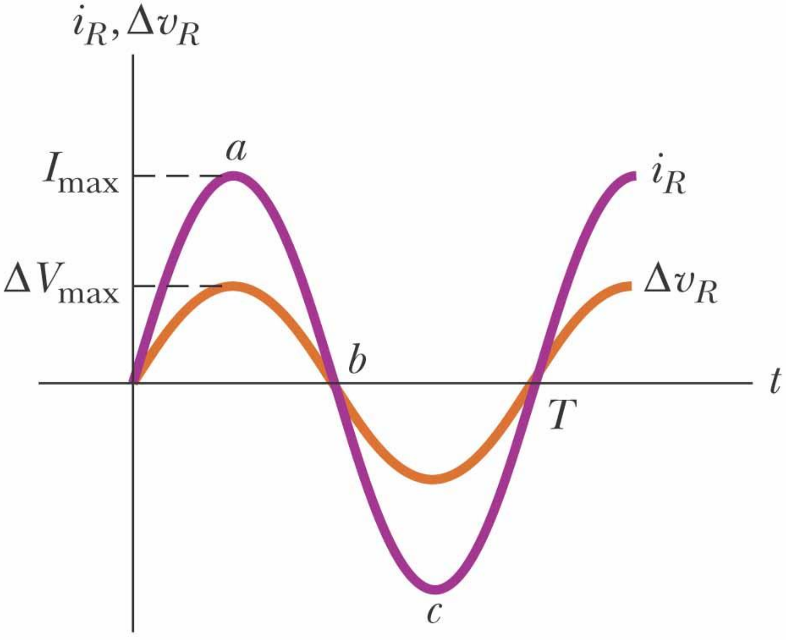
$$i_R = \frac{\Delta v_R}{R} = \frac{\Delta V_{max}}{R} \sin \omega t = I_{max} \sin \omega t$$

$$I_{max} = \frac{\Delta V_{max}}{R}$$

the maximum current:

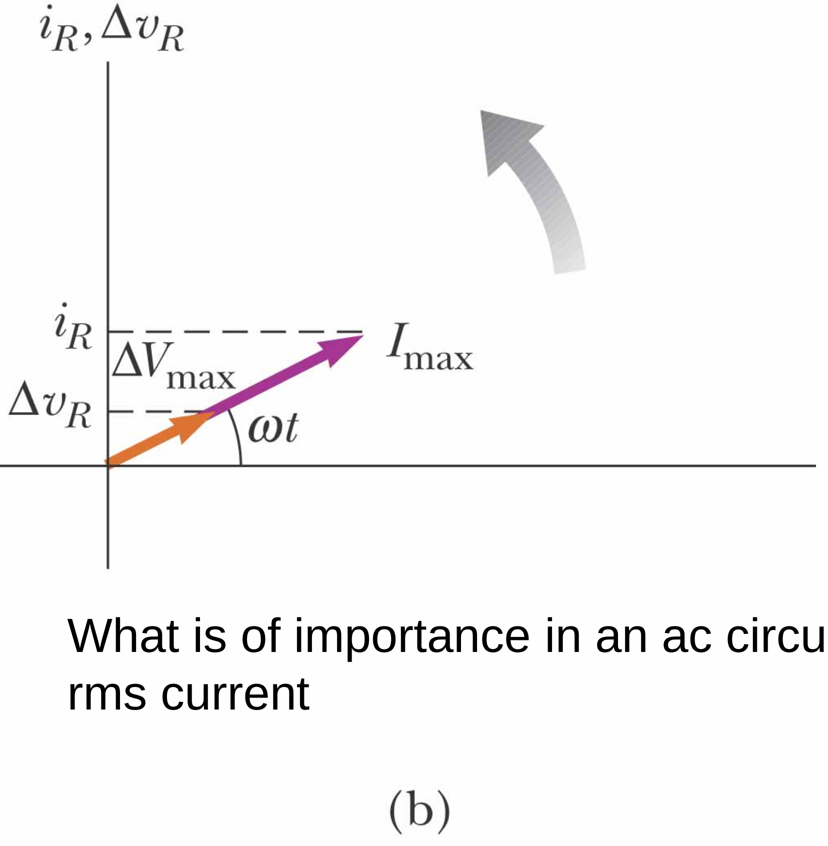
$$\Delta v_R = I_{max} R \sin \omega t$$


$i_R, \Delta v_R$
a
I_{max}
i_R
ΔV_{max}
Δv_R
b
t
T
c
(a)
$i_R, \Delta v_R$
i_R
I_{max}
ΔV_{max}
Δv_R
ωt
(b)



(a)

- **Plots of the instantaneous current i_R and instantaneous voltage Δv_R across a resistor as functions of time.**
- **The current is in phase with the voltage, which means that the current is zero when the voltage is zero, maximum when the voltage is maximum, and minimum when the voltage is minimum.**
- **At time $t = T$, one cycle of the time-varying voltage and current has been completed.**



Phasor diagram for the resistive circuit showing that the current is in phase with the voltage.

What is of importance in an ac circuit is an average value of current, referred to as the rms current

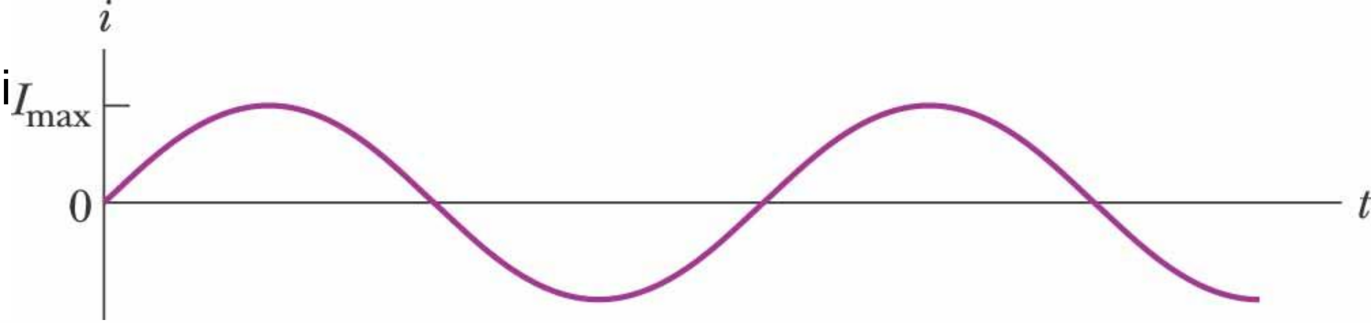
$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = 0.707 I_{max}$$

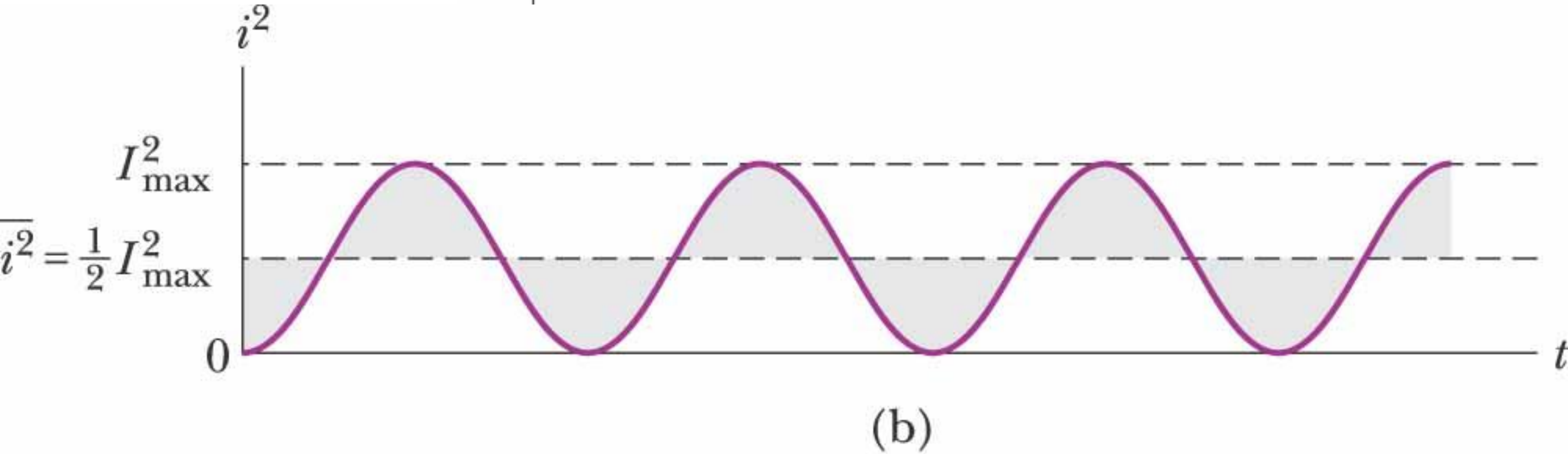
$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}} = 0.707 \Delta V_{max}$$

Average power delivered to a resistor

$$\mathcal{P}_{av} = I_{rms}^2 R$$

(a) Graph of the current i





(b) Graph of the current squared in a resistor as a function of time.

Notice that the gray shaded regions *under* the curve and *above* the dashed line for $I^2_{max}/2$ have the same area as the gray shaded regions *above* the curve and *below* the dashed line for $I^2_{max}/2$. Thus, the average value of i^2 is $I^2_{max}/2$.

What Is the rms Current?

The voltage output of a generator is given by $\Delta v = (200\text{ V})\sin \omega t$. Find the rms current in the circuit when this generator is connected to a 100 Ω- resistor.

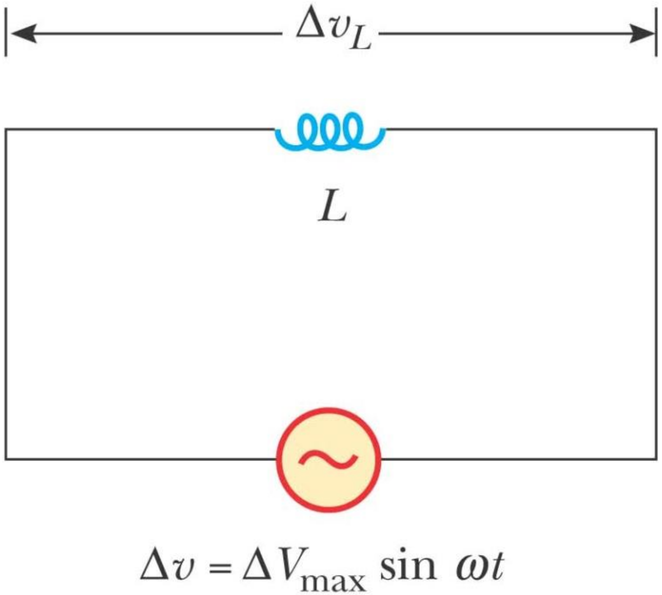
$$\Delta V_{\text{rms}} = \frac{\Delta V_{\text{max}}}{\sqrt{2}} = \frac{200\text{ V}}{\sqrt{2}} = 141\text{ V}$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{R} = \frac{141\text{ V}}{100\ \Omega} = \boxed{1.41\text{ A}}$$

Exercise Find the maximum current in the circuit.

Answer 2.00 A.

INDUCTORS IN AN AC CIRCUIT



If $\Delta v_L = \mathcal{E}_L = -L(di/dt)$

is the self-induced instantaneous voltage across the inductor.

$$\Delta v + \Delta v_L = 0,$$

$$\Delta v - L\frac{di}{dt} = 0$$

$$L\frac{di}{dt} = \Delta V_{\max} \sin \omega t$$

$$di = \frac{\Delta V_{\max}}{L} \sin \omega t \, dt$$

$$i_L = \frac{\Delta V_{\max}}{L} \int \sin \omega t \, dt = -\frac{\Delta V_{\max}}{\omega L} \cos \omega t$$

$$i_L = \frac{\Delta V_{\max}}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$I_{\max} = \frac{\Delta V_{\max}}{\omega L} = \frac{\Delta V_{\max}}{X_L}$$

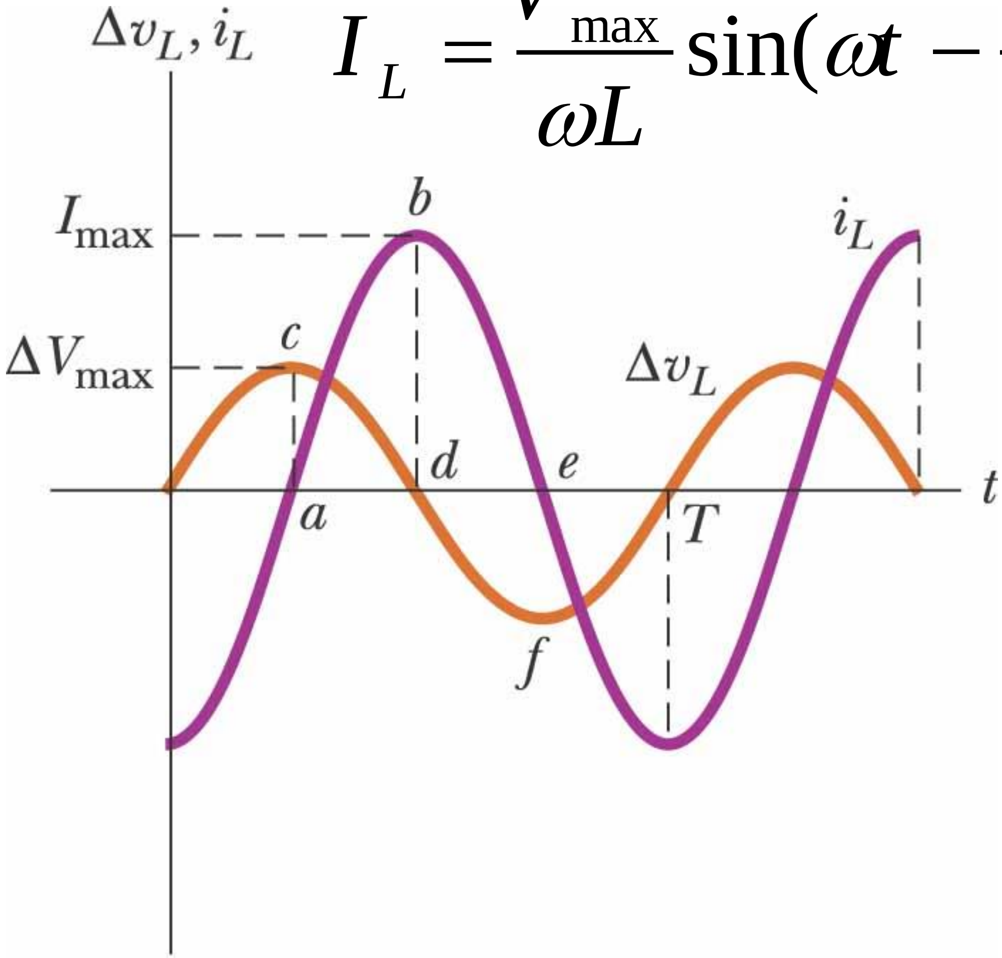
$$\boxed{X_L = \omega L}$$

the inductive reactance

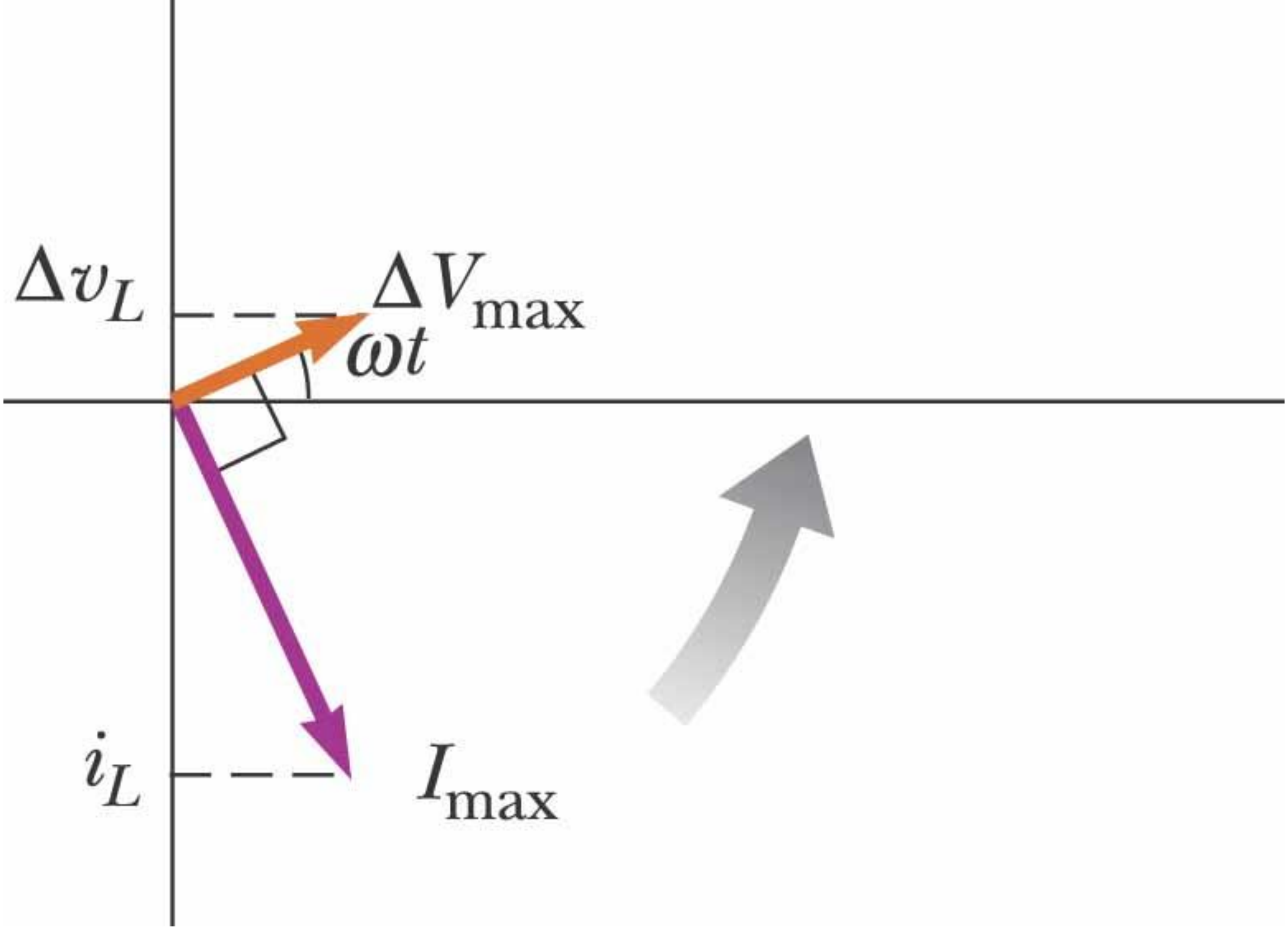
$$\Delta v_L = -L\frac{di}{dt} = -\Delta V_{\max}\sin\omega t = -I_{\max}X_L\sin\omega t$$

$$\Delta V_L = |\varepsilon| = L\frac{dI}{dt} = V_{\max}\sin\omega t$$

$$I_L = \frac{V_{\max}}{\omega L}\sin(\omega t - \frac{\pi}{2})$$



(a)



for a sinusoidal applied voltage, the current in an inductor always lags behind the voltage across the inductor by 90° (one-quarter cycle in time).

(b)

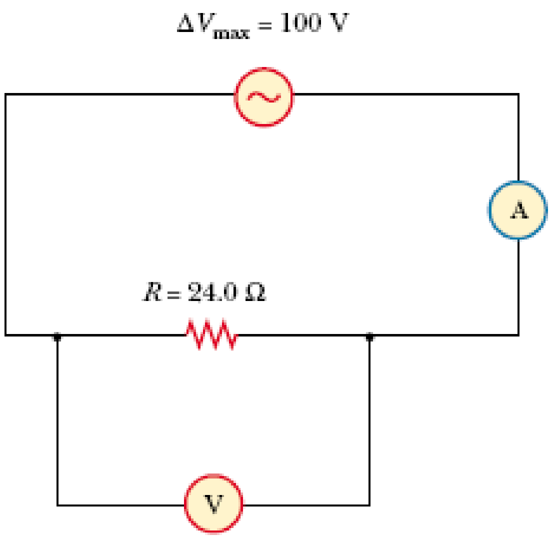
A Purely Inductive ac Circuit

In a purely inductive ac circuit, *L = 25.0 mH* and the rms voltage is 150 V. Calculate the inductive reactance and rms current in the circuit if the frequency is 60.0 Hz.

$$X_L = \omega L = 2\pi f L = 2\pi(60.0\ \text{Hz})(25.0 \times 10^{-3}\ \text{H}) = \boxed{9.42\ \Omega}$$

$$I_{\text{rms}} = \frac{\Delta V_{L,\text{rms}}}{X_L} = \frac{150\ \text{V}}{9.42\ \Omega} = \boxed{15.9\ \text{A}}$$

3. An ac power supply produces a maximum voltage $\Delta V_{max} = 100$ V. This power supply is connected to a 24.0-Ω resistor, and the current and resistor voltage are measured with an ideal ac ammeter and voltmeter, as shown in Figure P33.3. What does each meter read?



$$\Delta V_{rms} = \frac{100\text{ V}}{\sqrt{2}} = \boxed{70.7\text{ V}}$$

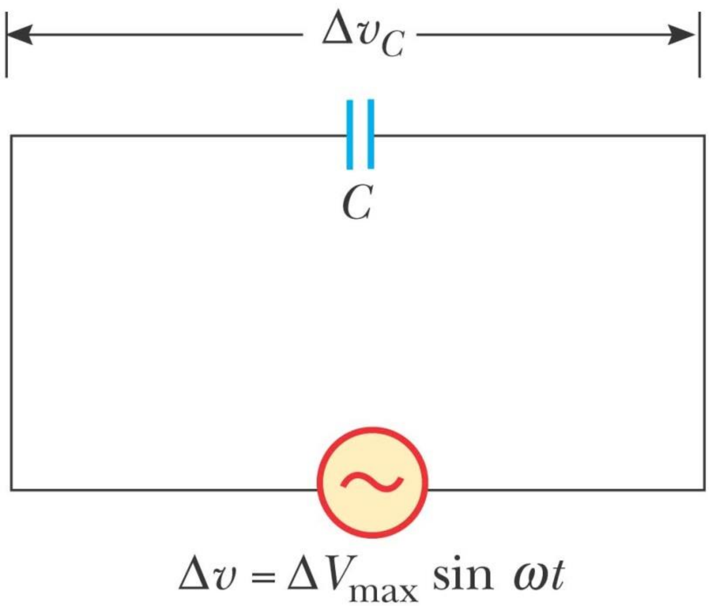
$$I_{rms} = \frac{\Delta V_{rms}}{R} = \frac{70.7\text{ V}}{24.0\ \Omega} = \boxed{2.95\text{ A}}$$

An inductor has a 54.0-Ω reactance at 60.0 Hz. What is the maximum current when this inductor is connected to a 50.0-Hz source that produces a 100-V rms voltage?

$$\text{At } 50.0\text{ Hz,}\quad X_L = 2\pi(50.0\text{ Hz})L = 2\pi(50.0\text{ Hz})\left(\frac{X_L\big|_{60.0\text{ Hz}}}{2\pi(60.0\text{ Hz})}\right) = \frac{50.0}{60.0}(54.0\ \Omega) = 45.0\ \Omega$$

$$I_{\max} = \frac{\Delta V_{\max}}{X_L} = \frac{\sqrt{2}\left(\Delta V_{\text{rms}}\right)}{X_L} = \frac{\sqrt{2}\left(100\text{ V}\right)}{45.0\ \Omega} = \boxed{3.14\text{ A}}$$

CAPACITORS IN AN AC CIRCUIT



$$\varepsilon - \Delta v_C = 0$$

$$\Delta v = \Delta v_C = \Delta V_{max} \sin \omega t$$

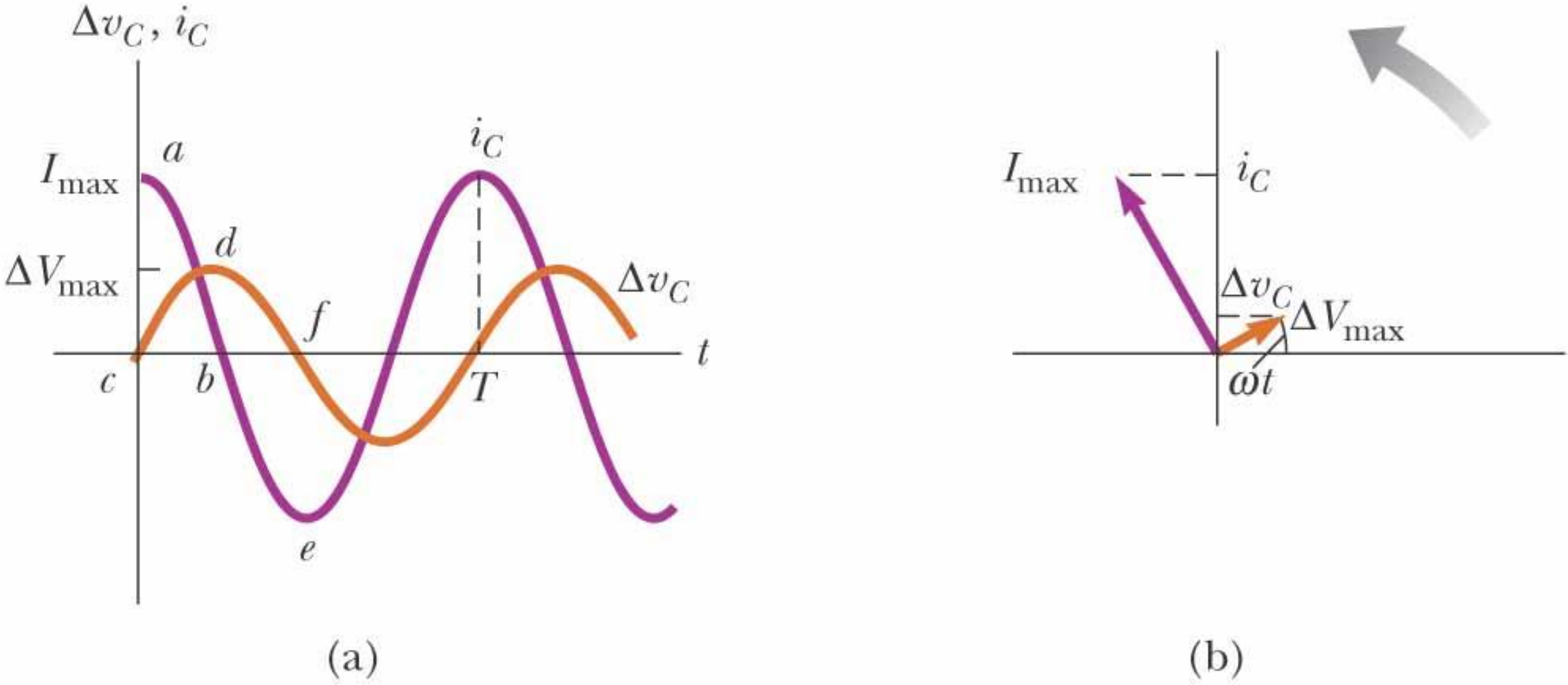
$$q = C \Delta V_{max} \sin \omega t$$

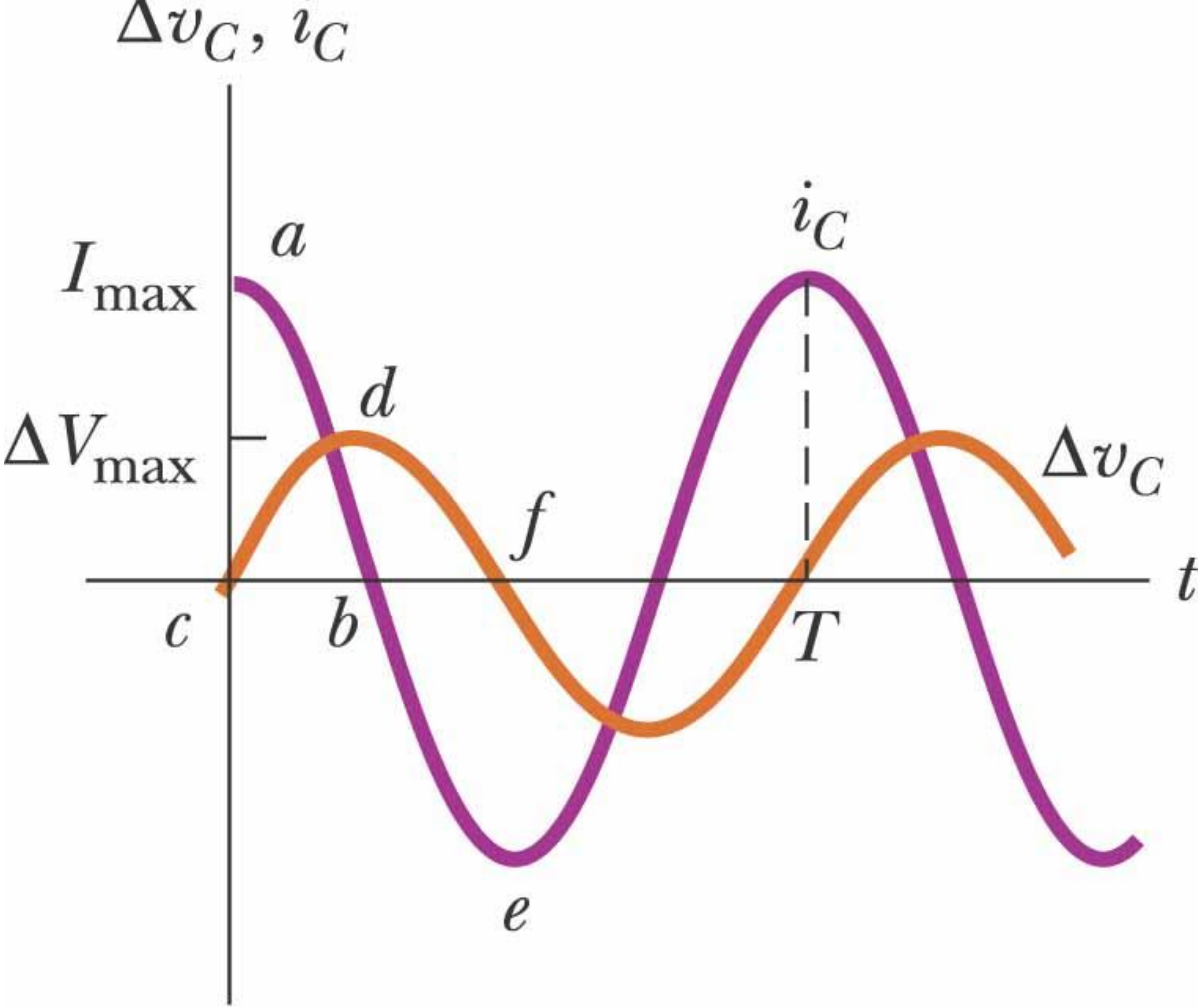
$$i_C = \frac{dq}{dt} = \omega C \Delta V_{max} \cos \omega t$$

$$\cos \omega t = \sin\left(\omega t + \frac{\pi}{2}\right)$$

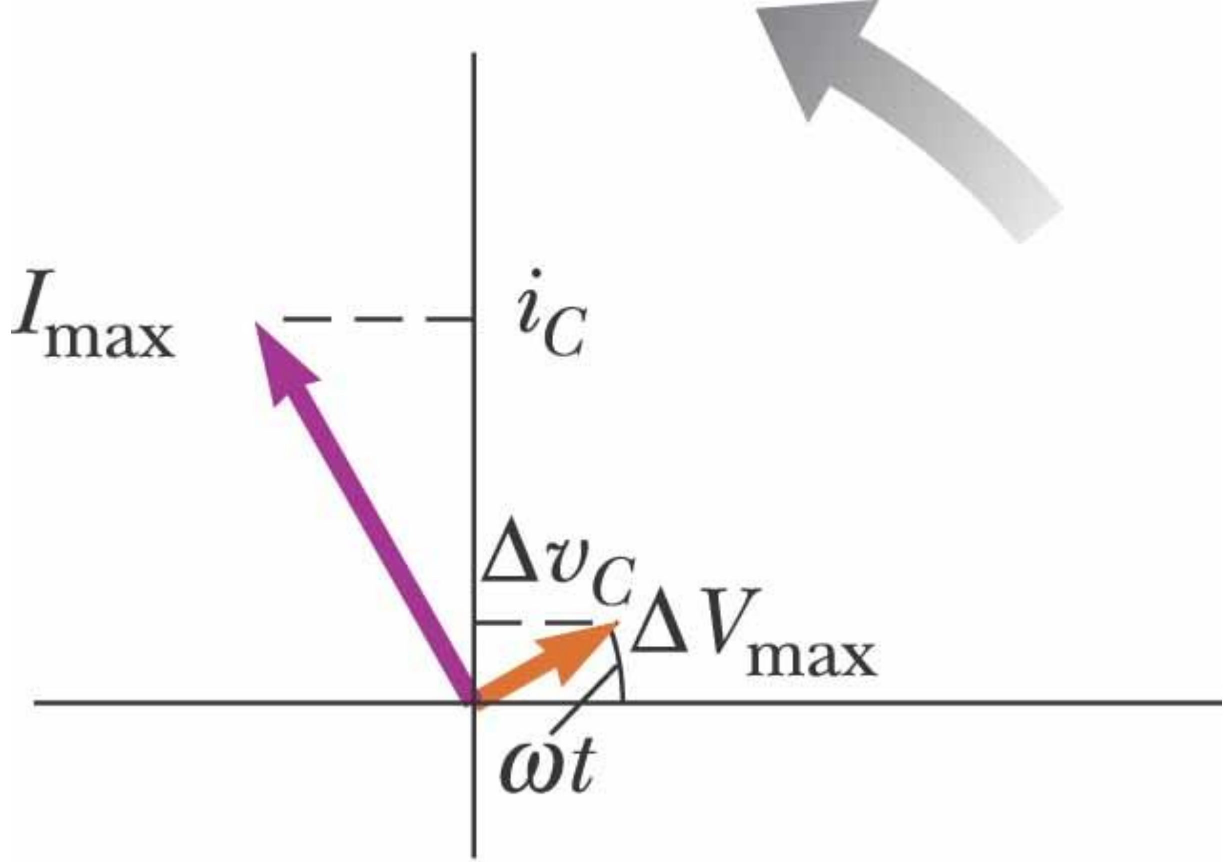
$$i_C = \omega C \Delta V_{max} \sin\left(\omega t + \frac{\pi}{2}\right)$$

for a sinusoidally applied voltage, the current in a capacitor always leads the voltage across the capacitor by 90°.





(a)



(b)

$$I_{\max} = \omega C \, \Delta V_{\max} = \frac{\Delta V_{\max}}{X_C}$$

The rms current is given by an expression similar to Equation 33.16, with $I_{\max}$ replaced by I_{rms} and $\Delta V_{\max}$ replaced by ΔV_{rms}.

$$\boxed{X_C = \frac{1}{\omega C}}$$

capacitive reactance:

Note that capacitive reactance also has units of ohms.

$$\Delta v_C = \Delta V_{\max} \sin \omega t = I_{\max} X_C \sin \omega t$$

A Purely Capacitive ac Circuit

An 8.00-μF capacitor is connected to the terminals of a 60.0-Hz ac generator whose rms voltage is 150 V. Find the capacitive reactance and the rms current in the circuit.

Solution Using Equation 33.17 and the fact that $\omega = 2\pi f = 377\ \text{s}^{-1}$ gives

$$X_C = \frac{1}{\omega C} = \frac{1}{(377\ \text{s}^{-1})(8.00 \times 10^{-6}\ \text{F})} = \boxed{332\ \Omega}$$

Hence, from a modified Equation 33.16, the rms current is

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{X_C} = \frac{150\ \text{V}}{332\ \Omega} = \boxed{0.452\ \text{A}}$$

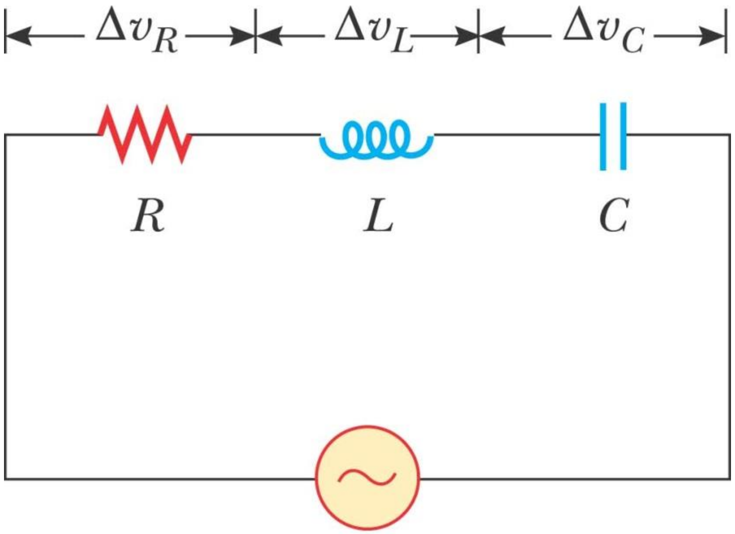
THE *RLC* SERIES CIRCUIT

$$\Delta v = \Delta V_{max} \sin \omega t$$

$$i = I_{max} \sin(\omega t - \phi)$$

Φ the phase angle between the current and the applied voltage

- the current at all points in a series ac circuit has the same amplitude and phase



(a)

$$\Delta v_R = I_{\max} R \sin \omega t = \Delta V_R \sin \omega t \tag{33.19}$$

$$\Delta v_L = I_{\max} X_L \sin\left(\omega t + \frac{\pi}{2}\right) = \Delta V_L \cos \omega t \tag{33.20}$$

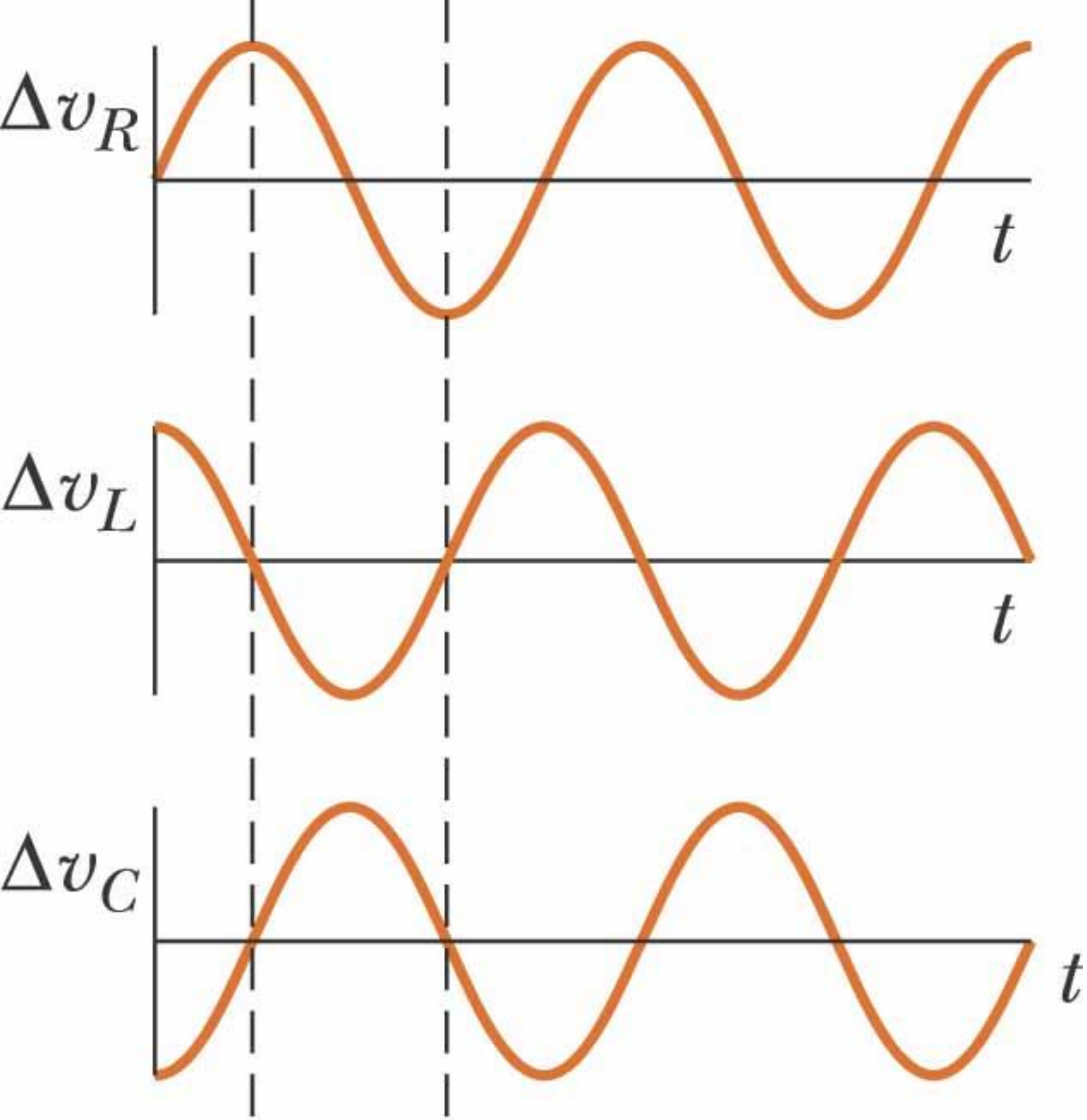
$$\Delta v_C = I_{\max} X_C \sin\left(\omega t - \frac{\pi}{2}\right) = -\Delta V_C \cos \omega t \tag{33.21}$$

where ΔV_R, ΔV_L, and ΔV_C are the maximum voltage values across the elements:

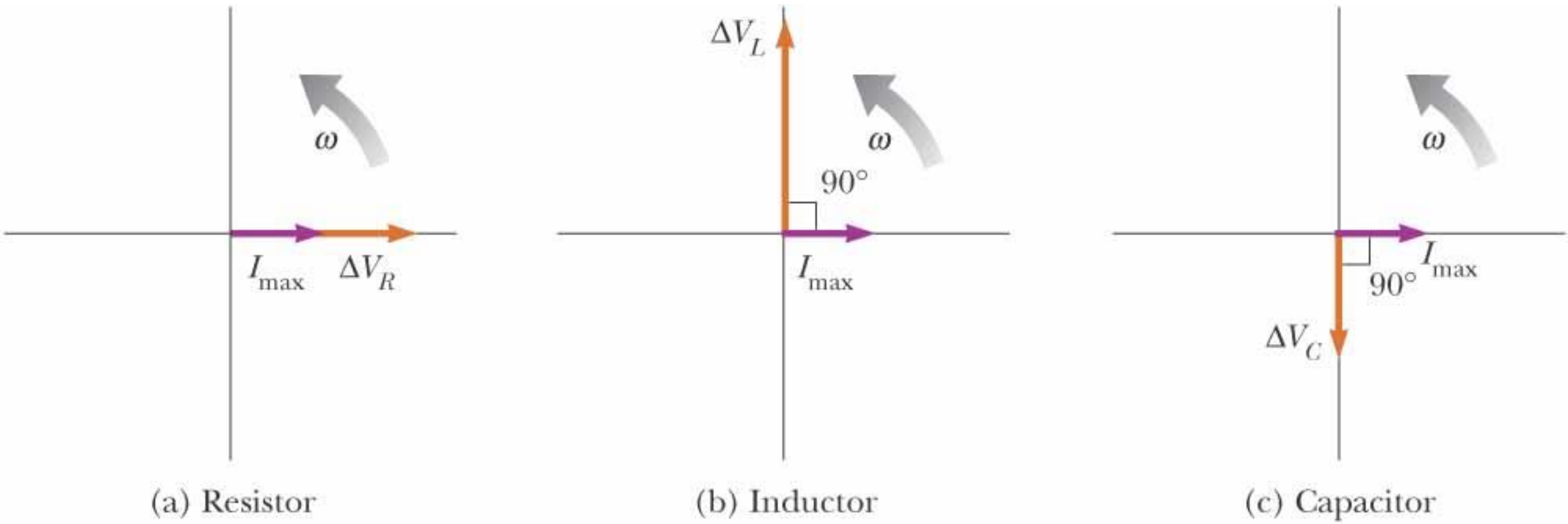
$$\Delta V_R = I_{\max} R \qquad \Delta V_L = I_{\max} X_L \qquad \Delta V_C = I_{\max} X_C$$

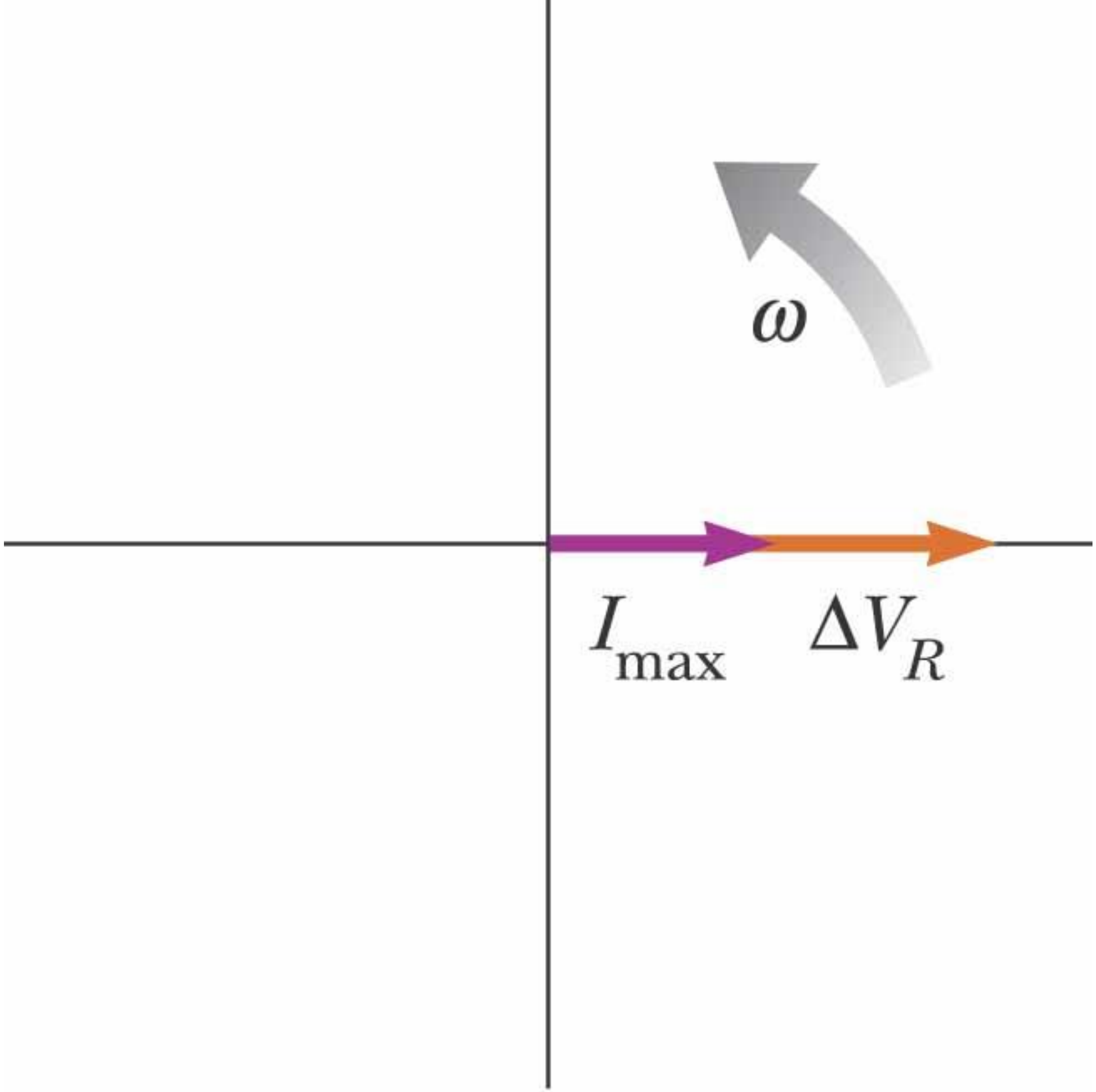
At this point, we could proceed by noting that the instantaneous voltage Δv across the three elements equals the sum

$$\Delta v = \Delta v_R + \Delta v_L + \Delta v_C$$

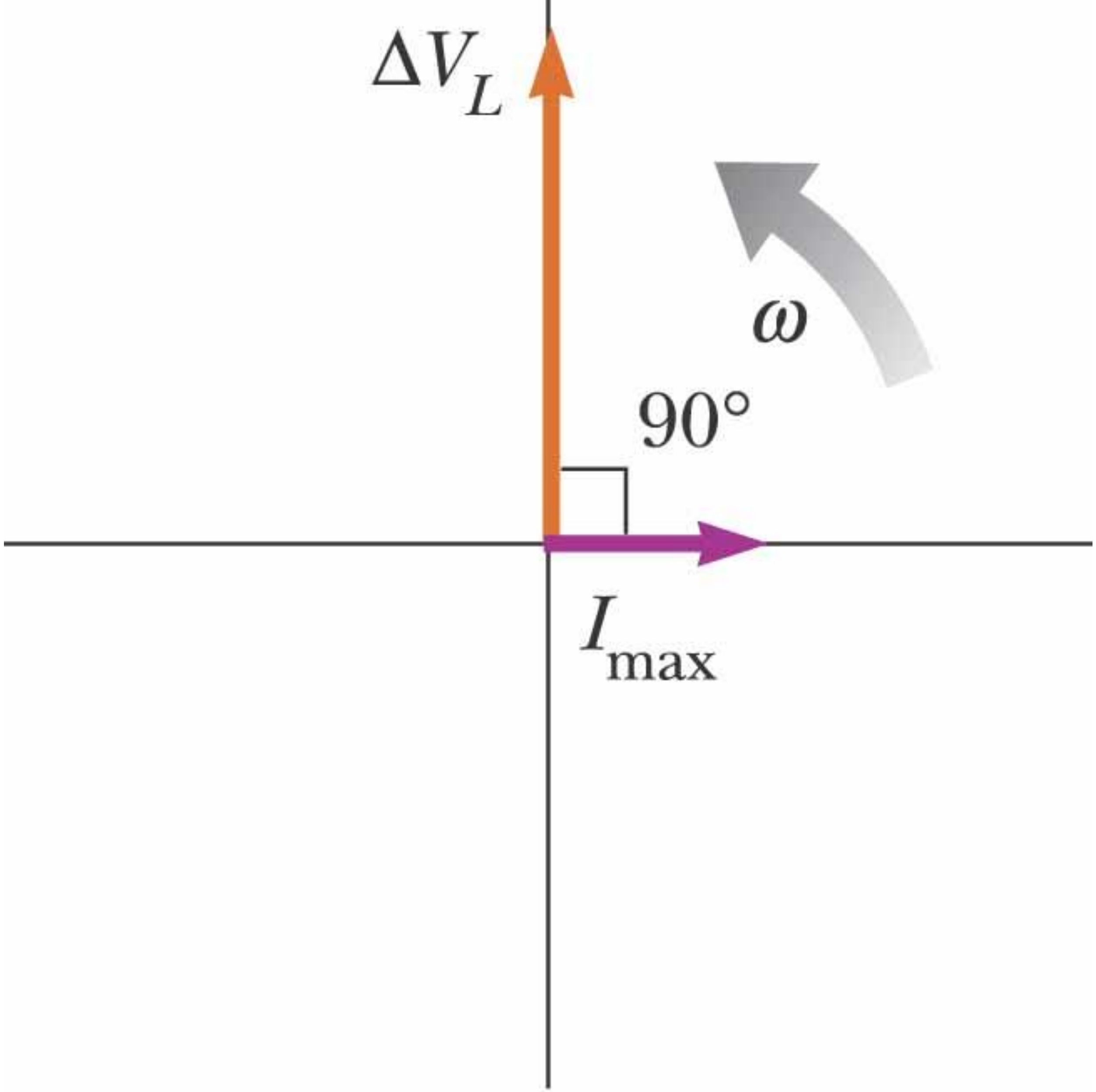


(b)

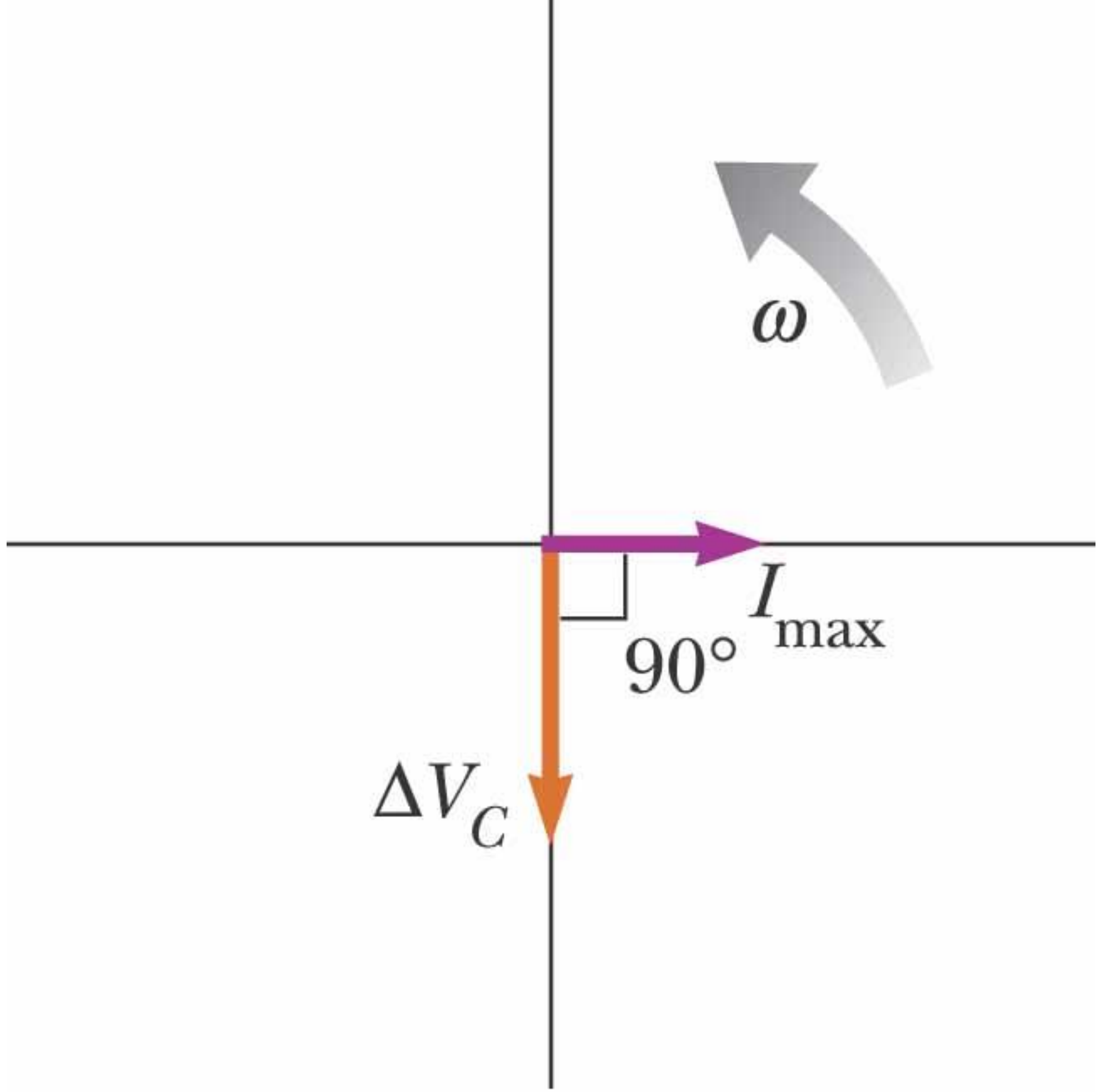

ω
I_{max}
ΔV_R
(a) Resistor
ΔV_L
ω
90°
I_{max}
(b) Inductor
ω
I_{max}
90°
ΔV_C
(c) Capacitor



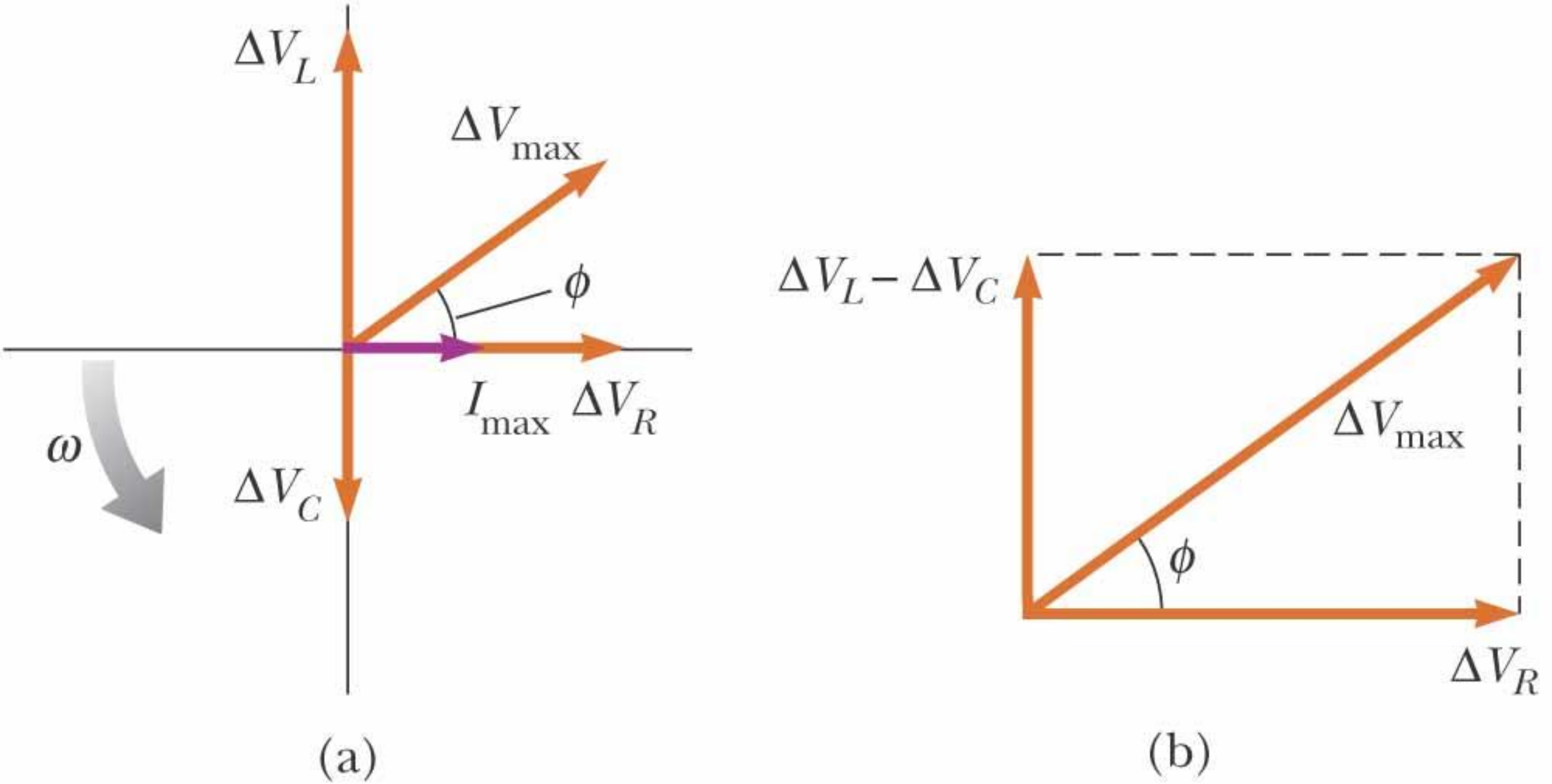
(a) Resistor



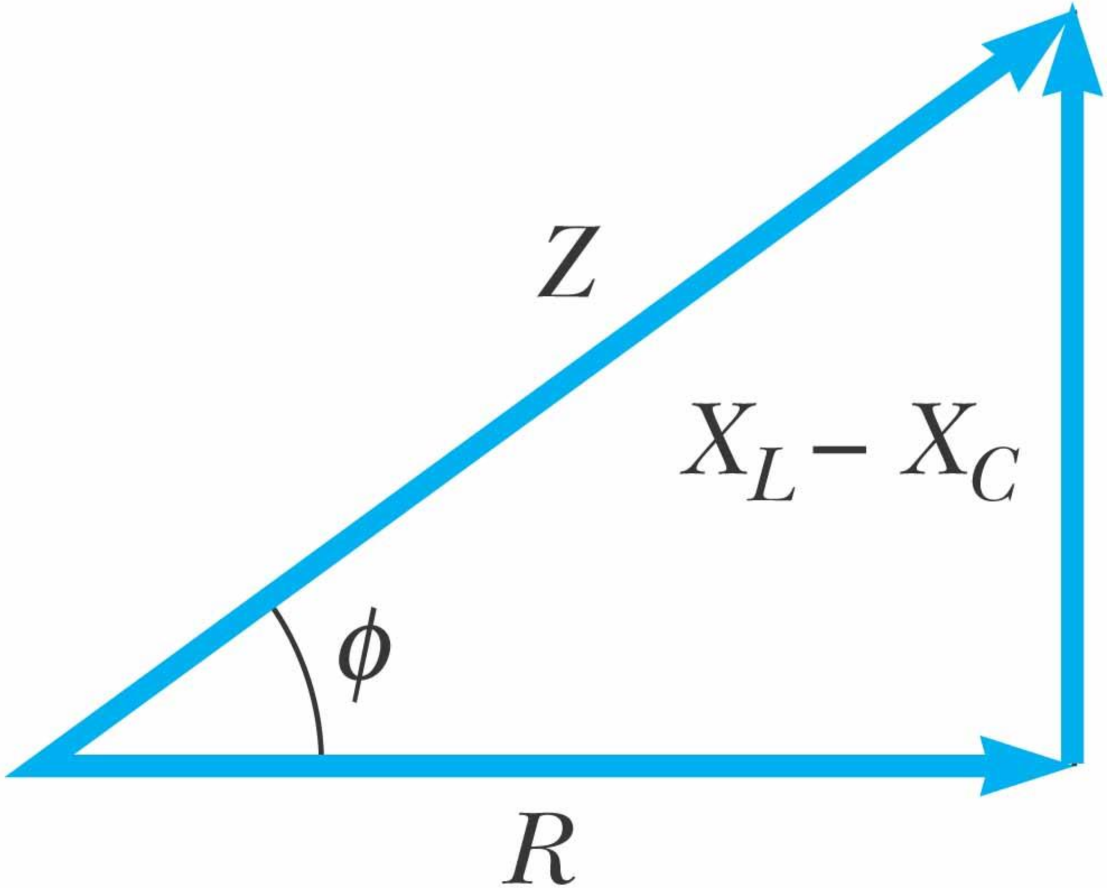
(b) Inductor



(c) Capacitor

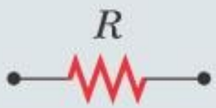
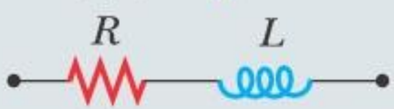
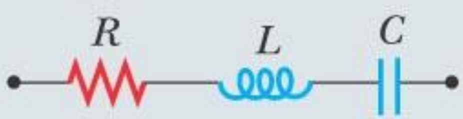


(a) Phasor diagram for the series *RLC* circuit The phasor Δ *VR* is in phase with the current phasor *I*max, the phasor Δ *VL* leads *I*max by 90°, and the phasor Δ*VC* lags *I*max by 90°. The total voltage Δ *V*max makes an Angle ϕ with *I*max. (b) Simplified version of the phasor diagram shown in part (a)



An impedance triangle for a series *RLC* circuit gives the relationship $Z \sqrt{} R^2 + (XL - XC)^2$

Table 33.1

Impedance Values and Phase Angles for Various Circuit-Element Combinations[a]		
Circuit Elements	**Impedance Z**	**Phase Angle ϕ**
	R	$0°$
	X_C	$-90°$
	X_L	$+90°$
	$\sqrt{R^2 + X_C^2}$	Negative, between $-90°$ and $0°$
	$\sqrt{R^2 + X_L^2}$	Positive, between $0°$ and $90°$
	$\sqrt{R^2 + (X_L - X_C)^2}$	Negative if $X_C > X_L$ Positive if $X_C < X_L$

[a] In each case, an AC voltage (not shown) is applied across the elements.

$$\Delta V_{\max} = \sqrt{\Delta V_R^2 + (\Delta V_L - \Delta V_C)^2} = \sqrt{(I_{\max} R)^2 + (I_{\max} X_L - I_{\max} X_C)^2}$$

$$\Delta V_{\max} = I_{\max} \sqrt{R^2 + (X_L - X_C)^2} \qquad \textbf{(33.22)}$$

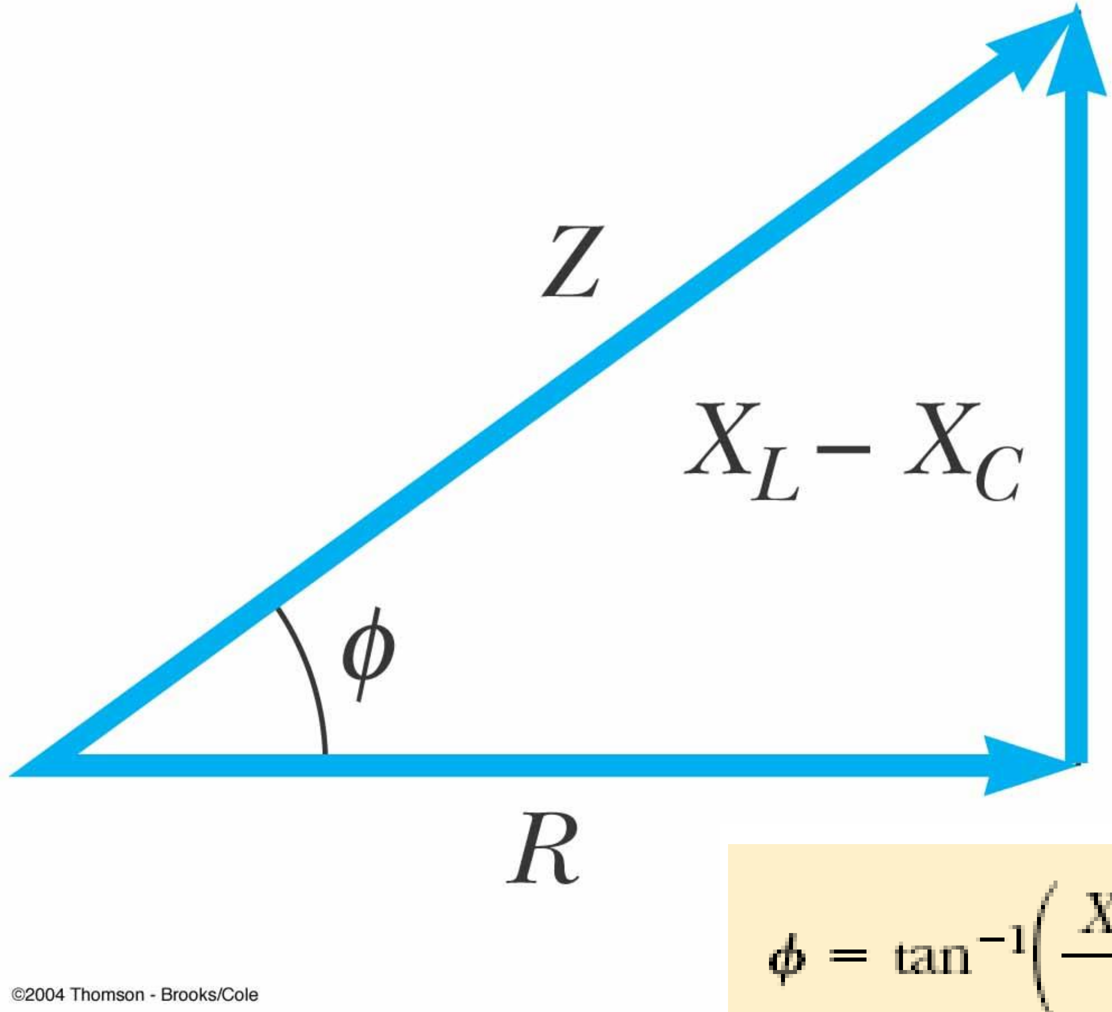
Therefore, we can express the maximum current as

$$I_{\max} = \frac{\Delta V_{\max}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

The **impedance** Z of the circuit is defined as

$$Z \equiv \sqrt{R^2 + (X_L - X_C)^2} \qquad \textbf{(33.23)}$$

$$\Delta V_{\max} = I_{\max} Z$$



$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

the phase angle

Also, from Figure 33.12, we see that $\cos \phi = R/Z$. When $X_L > X_C$ (which occurs at high frequencies), the phase angle is positive, signifying that the current lags behind the applied voltage, as in Figure 33.11a. When $X_L < X_C$, the phase angle is negative, signifying that the current leads the applied voltage. When $X_L = X_C$, the phase angle is zero. In this case, the impedance equals the resistance and the current has its maximum value, given by $\Delta V_{\max}/R$. The frequency at which this occurs is called the *resonance frequency;* it is described further in

Finding L from a Phasor Diagram

In a series RLC circuit, the applied voltage has a maximum value of 120 V and oscillates at a frequency of 60.0 Hz. The circuit contains an inductor whose inductance can be varied, a 200-Ω resistor, and a 4.00-μF capacitor. What value of L should an engineer analyzing the circuit choose such that the voltage across the capacitor lags the applied voltage by 30.0°?

Solution The phase relationships for the drops in voltage across the elements are shown in Figure 33.14. From the figure we see that the phase angle is $\phi = -60.0°$. This is because the phasors representing I_{max} and ΔV_R are in the same direction (they are in phase). From Equation 33.25, we find that

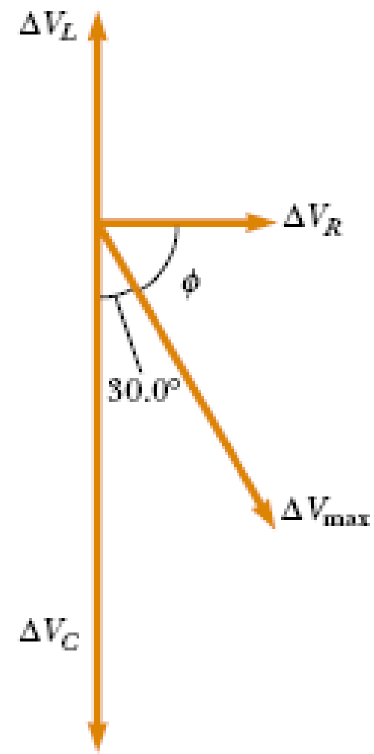
$$X_L = X_C + R \tan \phi$$

Substituting Equations 33.10 and 33.17 (with $\omega = 2\pi f$) into this expression gives

$$2\pi f L = \frac{1}{2\pi f C} + R \tan \phi$$

$$L = \frac{1}{2\pi f}\left[\frac{1}{2\pi f C} + R \tan \phi\right]$$

Substituting the given values into the equation gives $L =$ 0.84 H.



Analyzing a Series *RLC* Circuit

A series *RLC* ac circuit has $R = 425\ \Omega$, $L = 1.25$ H, $C = 3.50\ \mu$F, $\omega = 377\ \text{s}^{-1}$, and $\Delta V_{max} = 150$ V. (a) Determine the inductive reactance, the capacitive reactance, and the impedance of the circuit.

Solution The reactances are $X_L = \omega L = \boxed{471\ \Omega}$ and $X_C = 1/\omega C = \boxed{758\ \Omega.}$ The impedance is

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(425\ \Omega)^2 + (471\ \Omega - 758\ \Omega)^2} = \boxed{513\ \Omega}$$

(b) Find the maximum current in the circuit.

Solution

$$I_{max} = \frac{V_{max}}{Z} = \frac{150\text{ V}}{513\ \Omega} = \boxed{0.292\text{ A}}$$

(c) Find the phase angle between the current and voltage.

Solution

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{471\ \Omega - 758\ \Omega}{425\ \Omega}\right)$$

$$= \boxed{-34.0^\circ}$$

Because the circuit is more capacitive than inductive, ϕ is negative and the current leads the applied voltage.

(d) Find both the maximum voltage and the instantaneous voltage across each element.

Solution The maximum voltages are

$$\Delta V_R = I_{\text{max}} R = (0.292\text{ A})(425\ \Omega) = \boxed{124\text{ V}}$$

$$\Delta V_L = I_{\text{max}} X_L = (0.292\text{ A})(471\ \Omega) = \boxed{138\text{ V}}$$

$$\Delta V_C = I_{\text{max}} X_C = (0.292\text{ A})(758\ \Omega) = \boxed{221\text{ V}}$$

Using Equations 33.19, 33.20, and 33.21, we find that we can write the instantaneous voltages across the three elements as

$$\Delta v_R = \boxed{(124\text{ V})\sin 377t}$$

$$\Delta v_L = \boxed{(138\text{ V})\cos 377t}$$

$$\Delta v_C = \boxed{(-221\text{ V})\cos 377t}$$

POWER IN AN AC CIRCUIT

No power losses are associated with pure capacitors and pure inductors in an ac circuit

When the current begins to increase in one direction in an ac circuit, charge begins to accumulate on the capacitor, and a voltage drop appears across it. When this voltage drop reaches its maximum value, the energy stored in the capacitor is

$$\frac{1}{2}C(\Delta V_{\max})^2.$$

However, this energy storage is only momentary. The capacitor is charged and discharged twice during each cycle: Charge is delivered to the capacitor during two quarters of the cycle and is returned to the voltage source during the remaining two quarters. **Therefore, the average power supplied by the source is zero**. **In other words, no power losses occur in a capacitor in an ac circuit.**

For the *RLC circuit* , we can express the instantaneous power P

$$\mathcal{P} = i\,\Delta v = I_{\max}\sin(\omega t - \phi)\,\Delta V_{\max}\sin\omega t$$
$$= I_{\max}\,\Delta V_{\max}\sin\omega t\sin(\omega t - \phi)$$

The average power

$$\mathcal{P}_{\mathrm{av}} = \tfrac{1}{2} I_{\max}\,\Delta V_{\max}\cos\phi$$

$$\mathcal{P}_{\mathrm{av}} = I_{\mathrm{rms}}\,\Delta V_{\mathrm{rms}}\cos\phi$$

the quantity cos φ is called **the power factor**

the maximum voltage drop across the resistor is given by

$$\Delta V_{\max}\cos\phi = I_{\max}R.$$

$$\cos\phi = I_{\max}R/\Delta V_{\max},$$

$$\mathcal{P}_{av} = I_{rms}\,\Delta V_{rms}\cos\phi = I_{rms}\left(\frac{\Delta V_{\max}}{\sqrt{2}}\right)\frac{I_{\max}R}{\Delta V_{\max}} = I_{rms}\frac{I_{\max}R}{\sqrt{2}}$$

$$\mathcal{P}_{av} = I_{rms}^2 R$$

In words, **the average power delivered by the generator is converted to internal energy in the resistor, just as in the case of a dc circuit. No power loss occurs in an ideal inductor or capacitor.**

When the load is purely resistive, then $\varphi = 0$, $\cos\varphi = 1$, and

$$\mathcal{P}_{av} = I_{rms}\,\Delta V_{rms}$$

Average Power in an *RLC* Series Circuit

Calculate the average power delivered to the series *RLC* circuit described in Example 33.6.

Solution First, let us calculate the rms voltage and rms current, using the values of ΔV_{max} and I_{max} from Example 33.6:

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}} = \frac{150\ \text{V}}{\sqrt{2}} = 106\ \text{V}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{0.292\ \text{A}}{\sqrt{2}} = 0.206\ \text{A}$$

Because $\phi = -34.0°$, the power factor, $\cos\phi$, is 0.829; hence, the average power delivered is

$$\mathcal{P}_{av} = I_{rms}\,\Delta V_{rms}\cos\phi = (0.206\ \text{A})(106\ \text{V})(0.829)$$

$$= \boxed{18.1\ \text{W}}$$

We can obtain the same result using Equation 33.30.

RESONANCE IN A SERIES *RLC* CIRCUIT

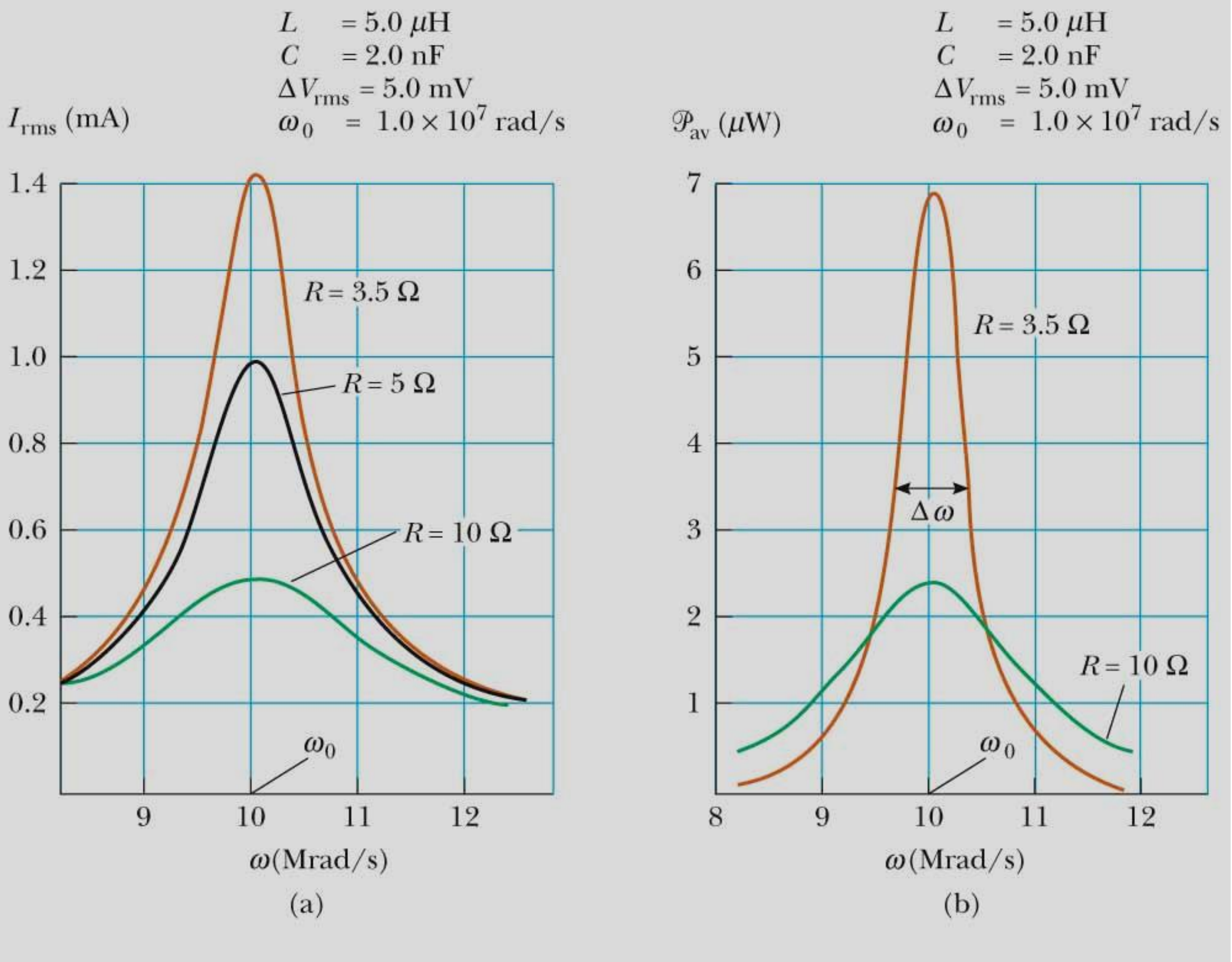
A series *RLC circuit is said to be in resonance when the current has its maximum* value. In general, the rms current can be written

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z}$$

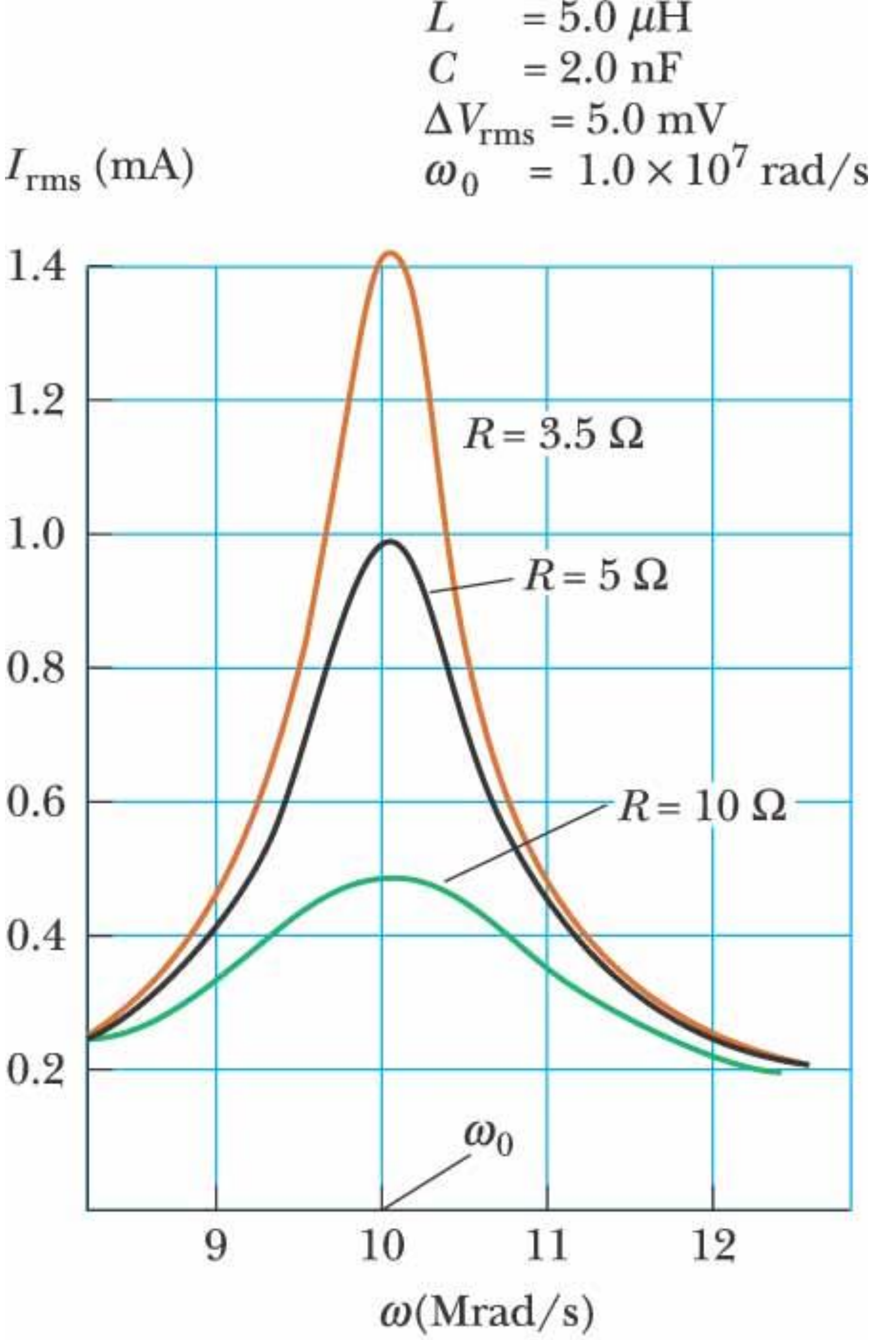
$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

Because the impedance depends on the frequency of the source, the current in the *RLC circuit also depends on the frequency. The frequency* ω_0 *at which* $X_L - X_C = 0$ is called the resonance frequency of the circuit. To find ω_0, we use the condition $XL = XC$,from which we obtain , $\omega_0 L = 1/\omega_0 C$ or

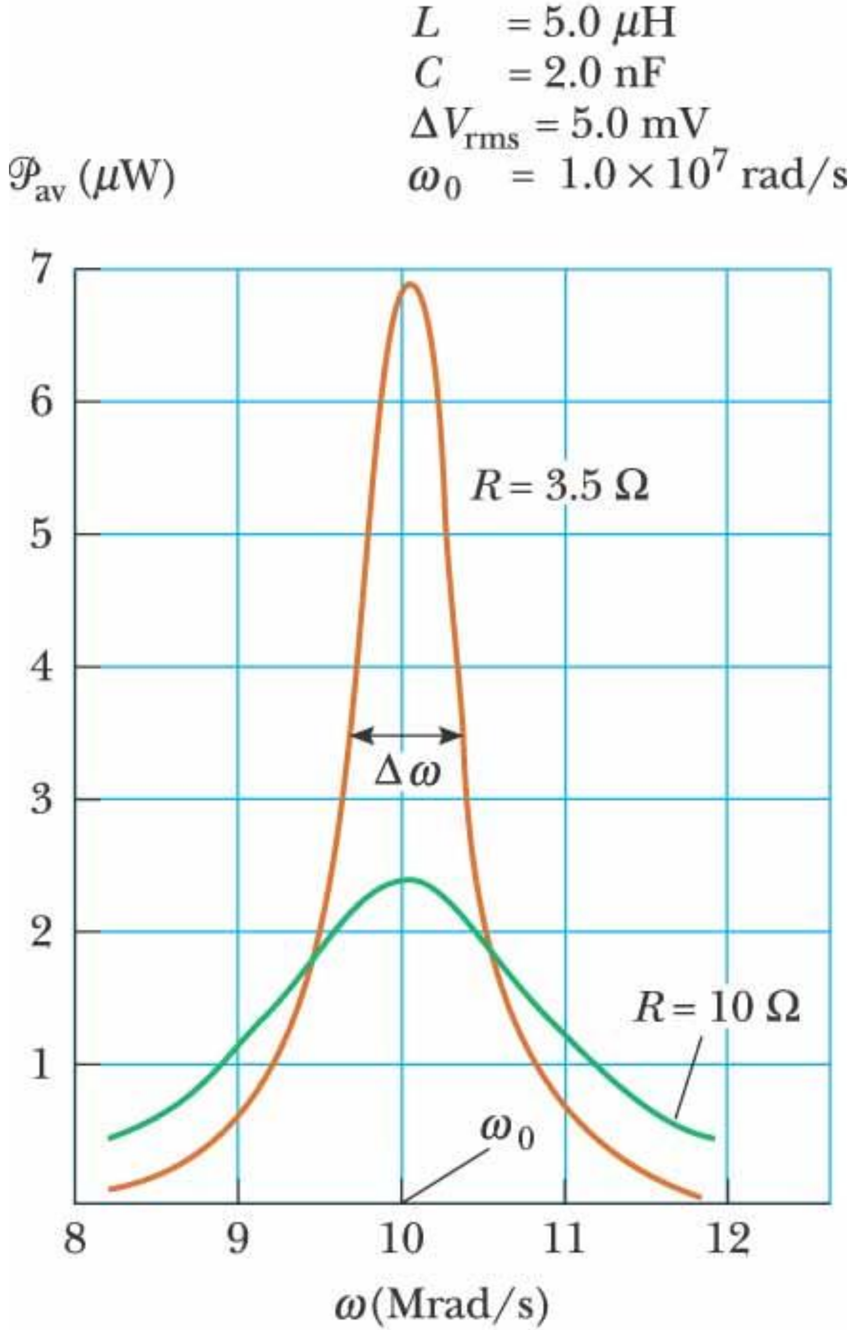
$$\omega_0 = \frac{1}{\sqrt{LC}}$$



(a) The rms current versus frequency for a series *RLC* circuit, for three values of *R*. The current reaches its maximum value at the resonance frequency ω_0. (b) Average power delivered to the circuit versus frequency for the series *RLC* circuit, for two values of *R*.

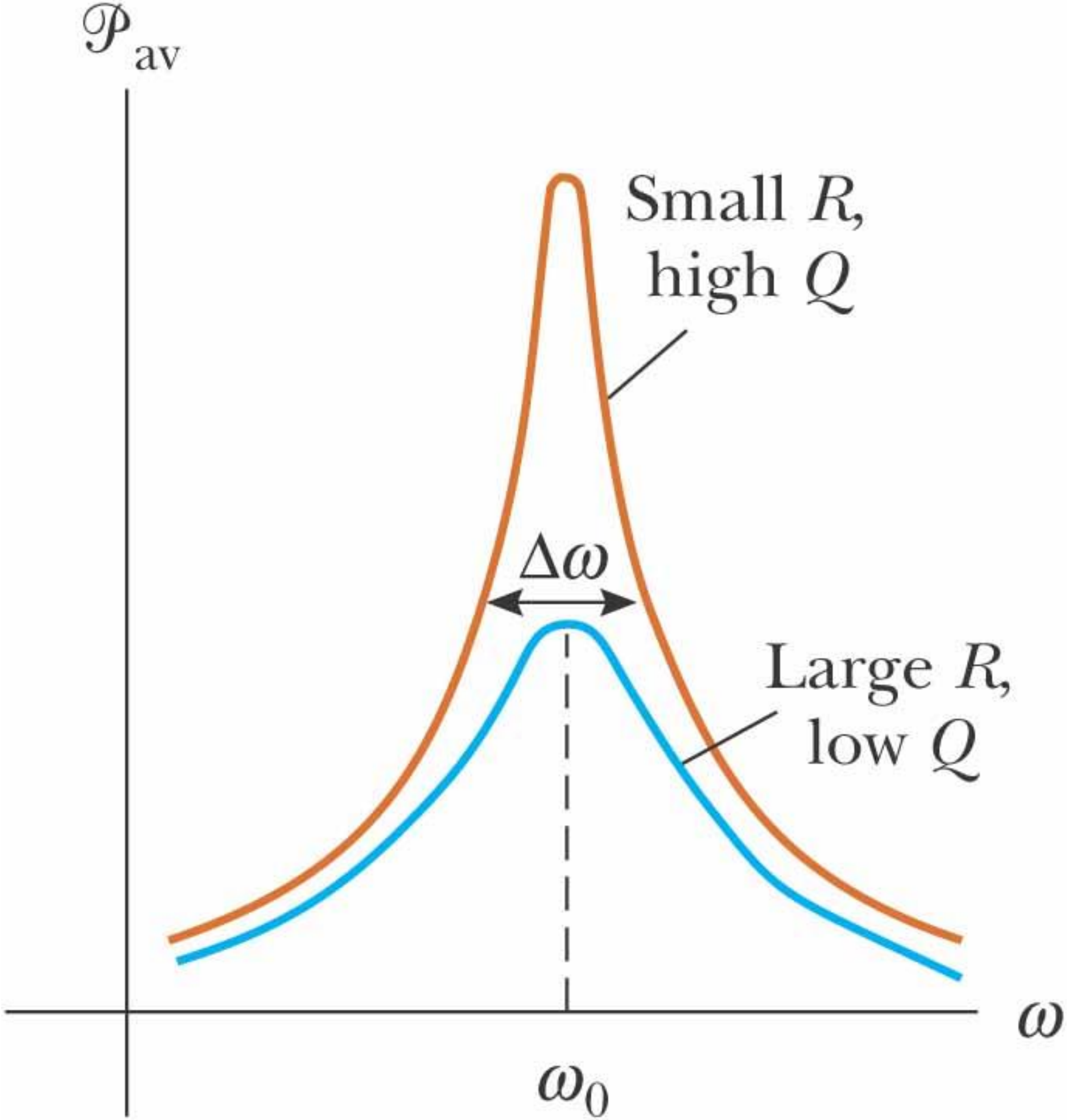

$L = 5.0\ \mu H$
$C = 2.0\ nF$
$\Delta V_{rms} = 5.0\ mV$
$\omega_0 = 1.0 \times 10^7$ rad/s
I_{rms} (mA)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
$R = 3.5\ \Omega$
$R = 5\ \Omega$
$R = 10\ \Omega$
ω_0
9
10
11
12
ω(Mrad/s)

(a)

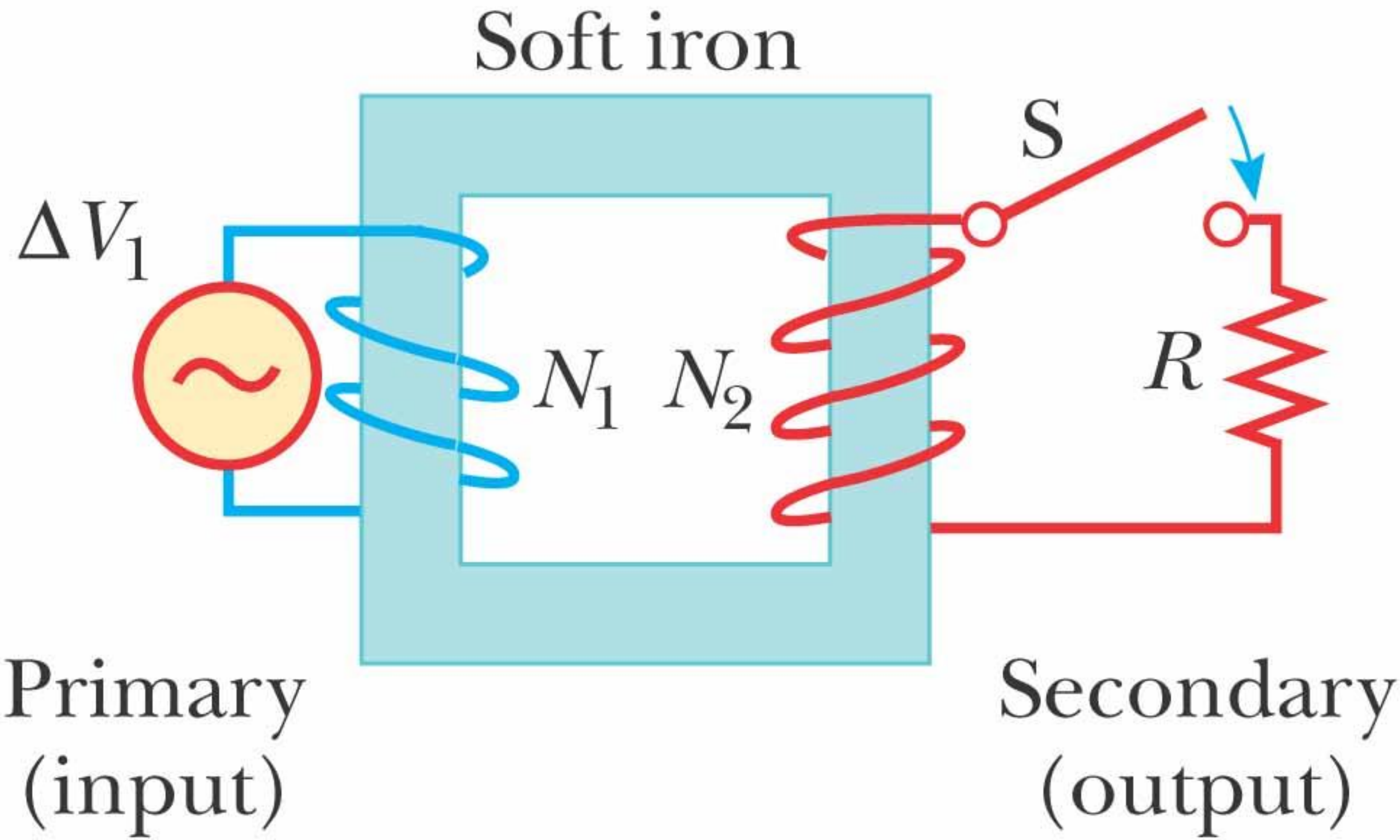


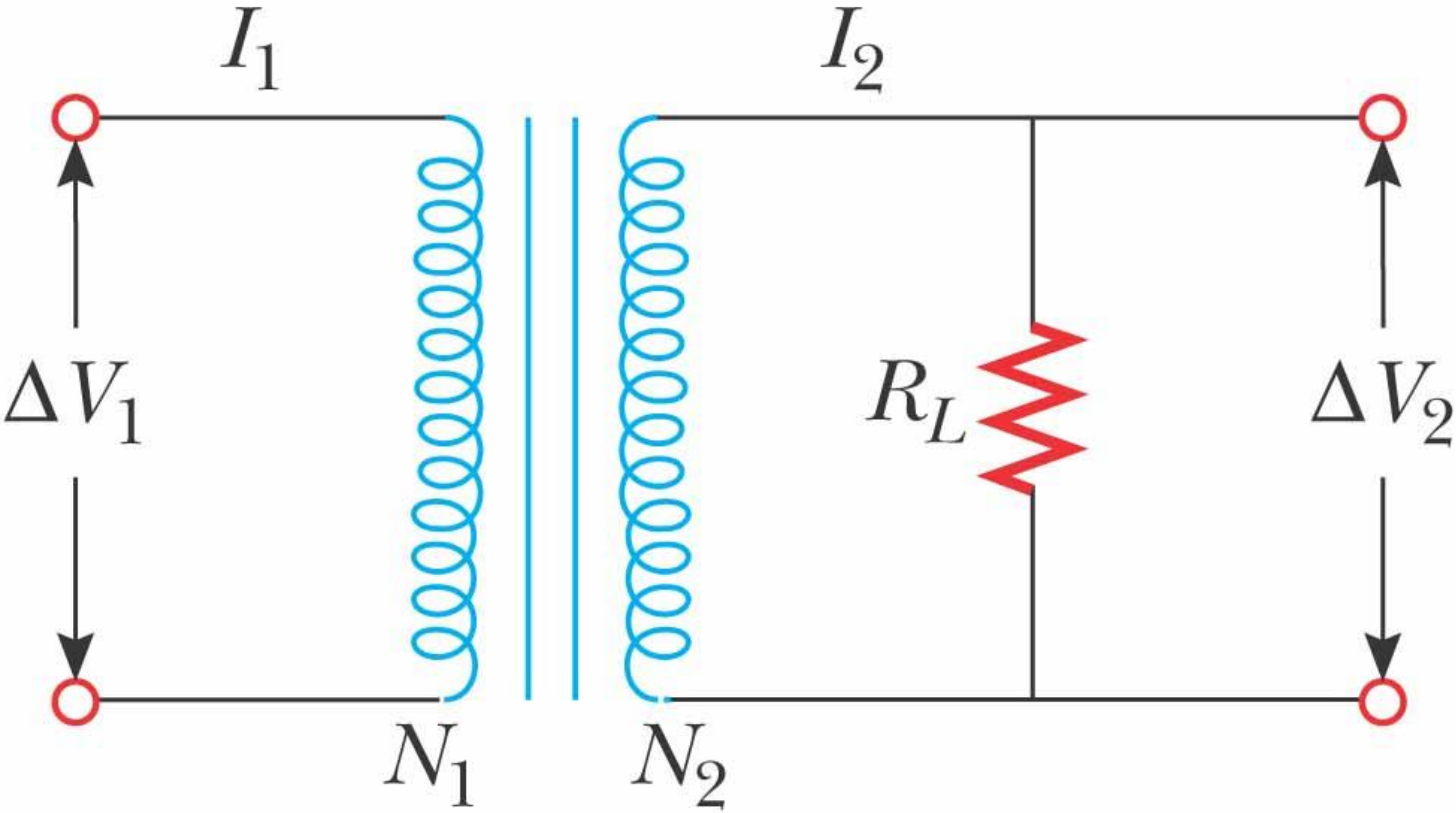
$L = 5.0\ \mu H$
$C = 2.0\ nF$
$\Delta V_{rms} = 5.0\ mV$
$\omega_0 = 1.0 \times 10^7\ rad/s$
$\mathcal{P}_{av}\ (\mu W)$
7
6
5
4
3
2
1
$R = 3.5\ \Omega$
$\Delta\omega$
$R = 10\ \Omega$
ω_0
8
9
10
11
12
ω(Mrad/s)

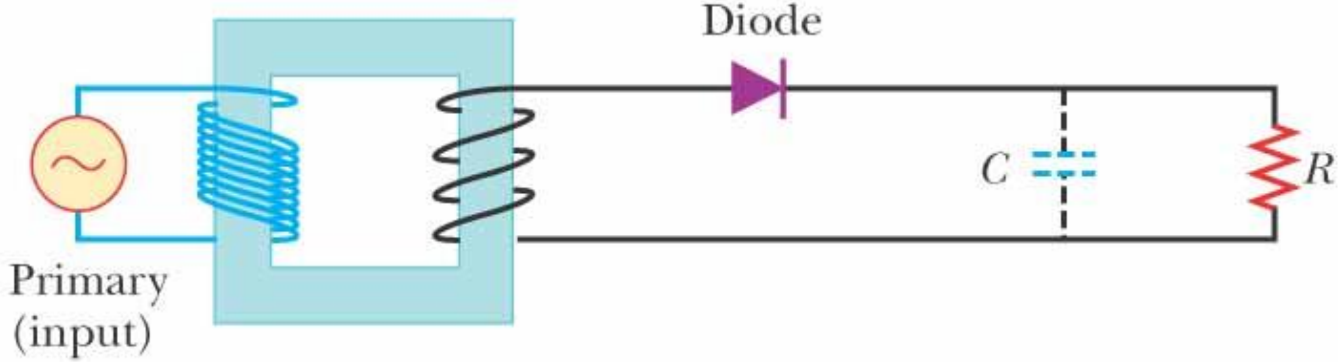
(b)


$\mathcal{P}_{av}$
Small R, high Q
$\Delta\omega$
Large R, low Q
ω
ω_0

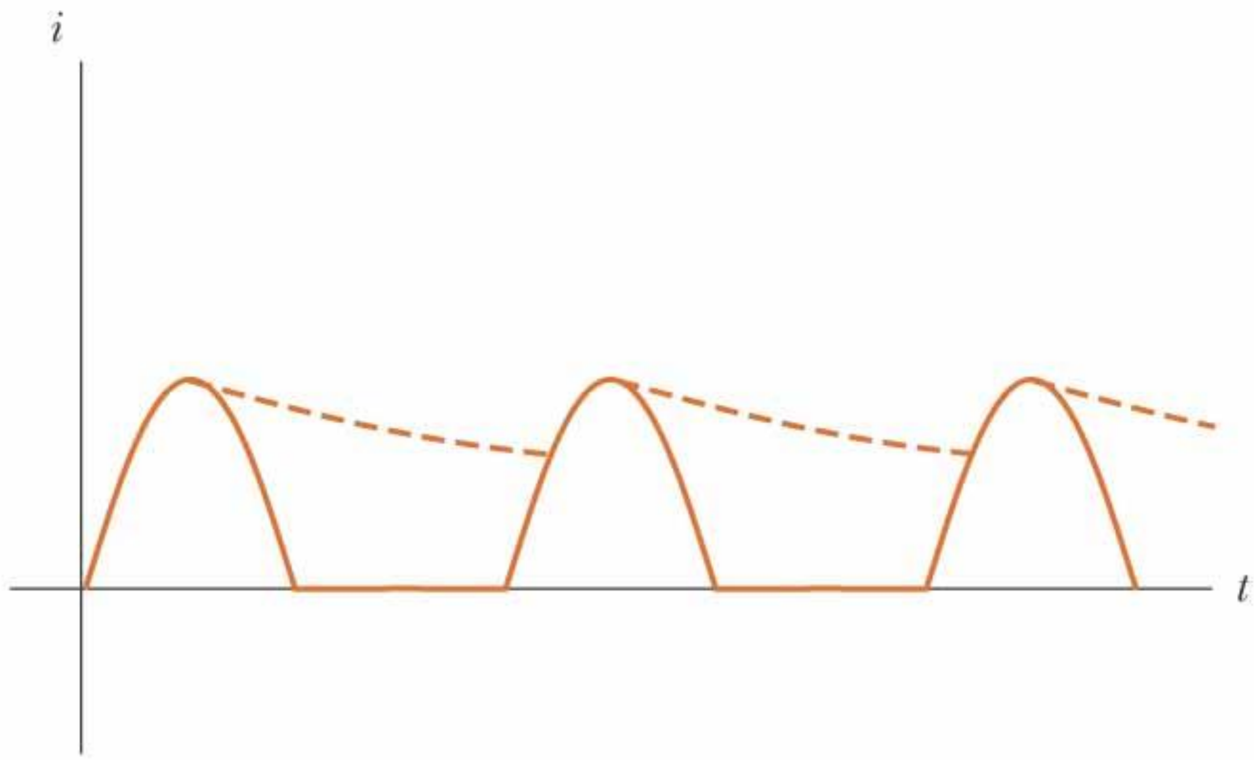
Slide 48


Soft iron
S
ΔV_1
N_1
N_2
R
Primary
(input)
Secondary
(output)

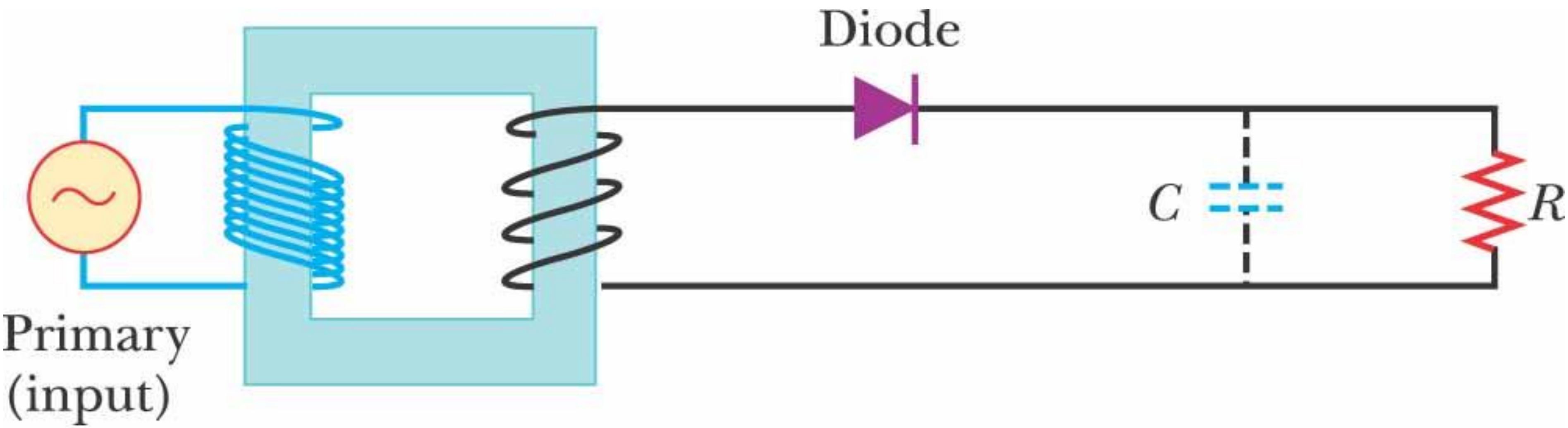

I_1
I_2
ΔV_1
R_L
ΔV_2
N_1
N_2



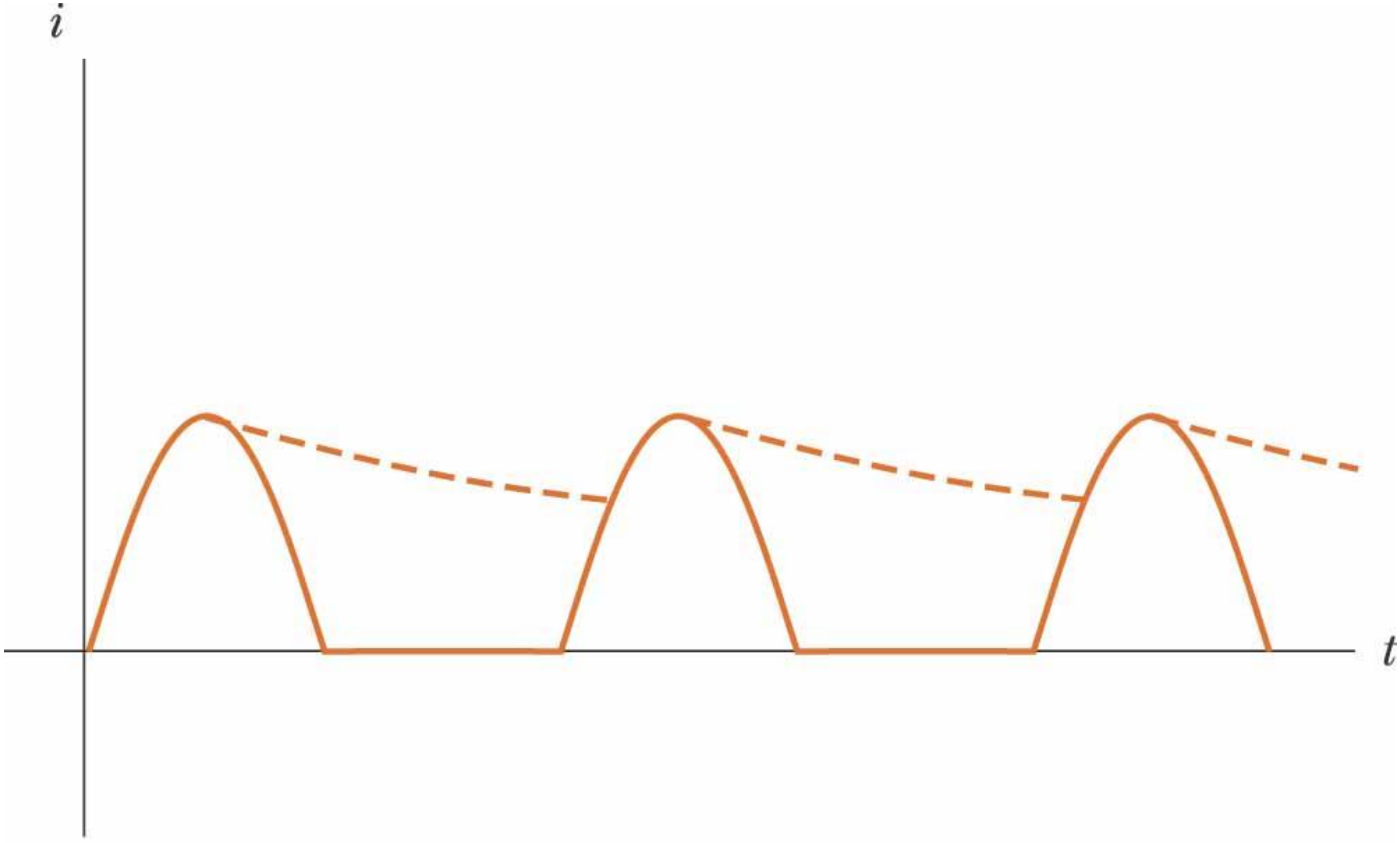
(a)



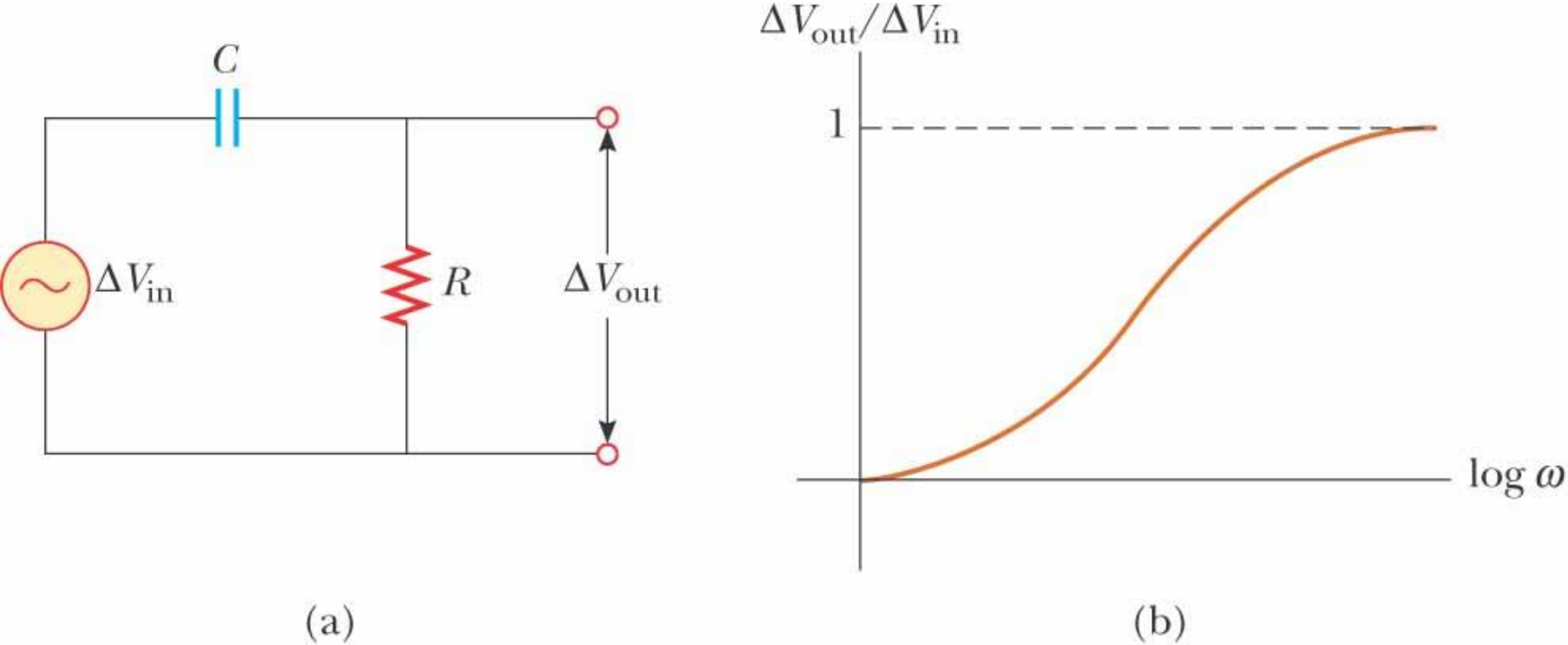
(b)



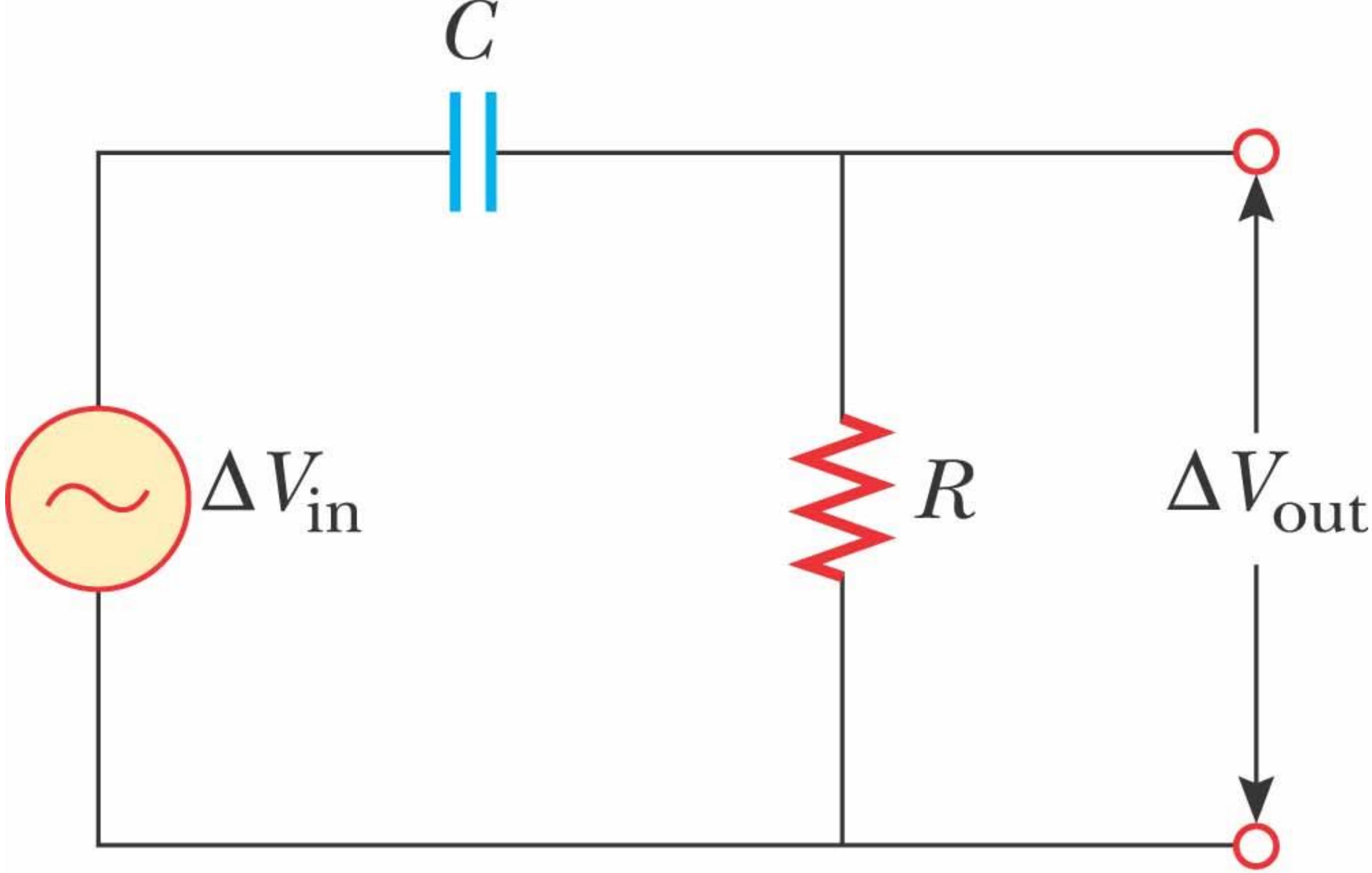
(a)



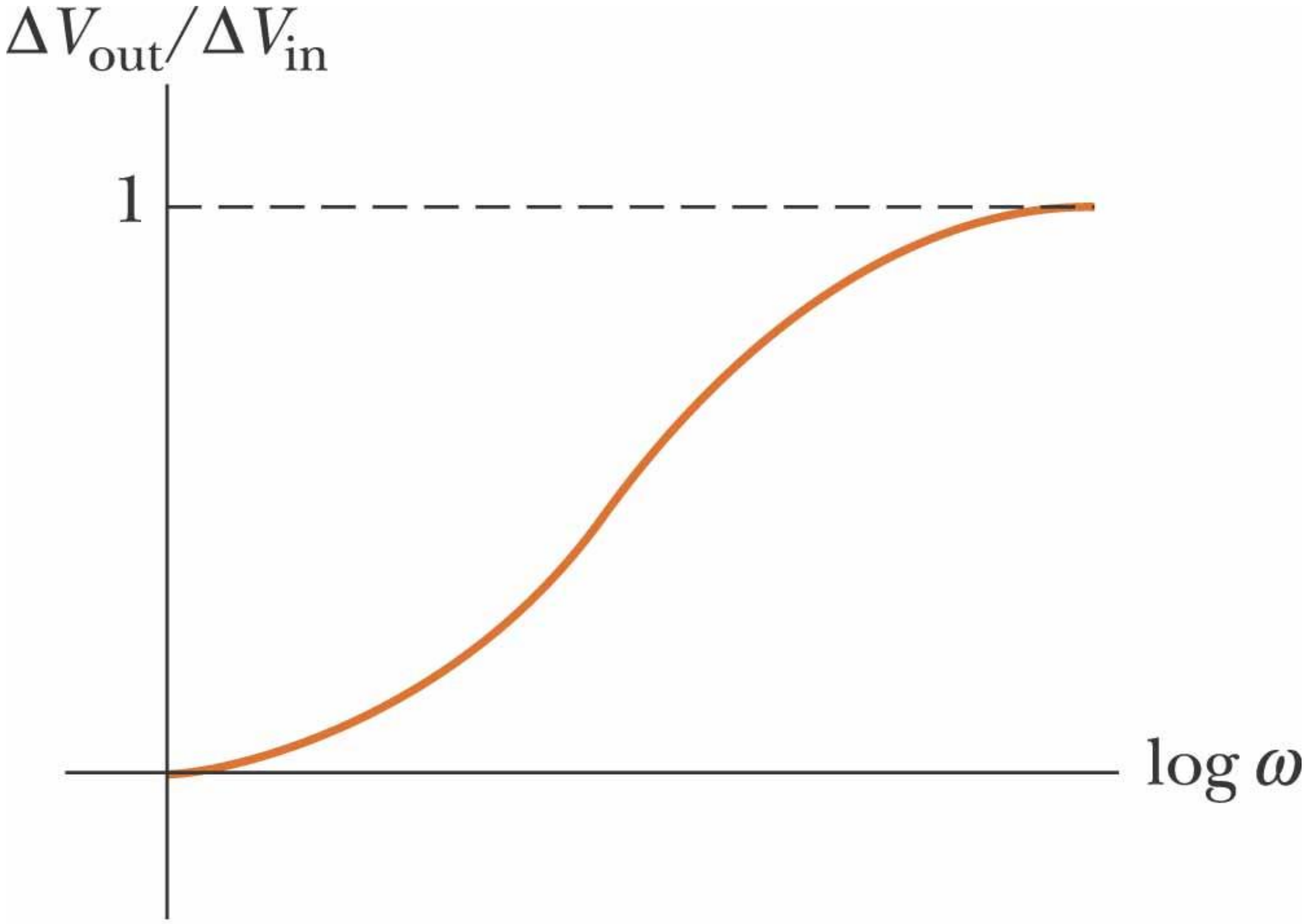
(b)



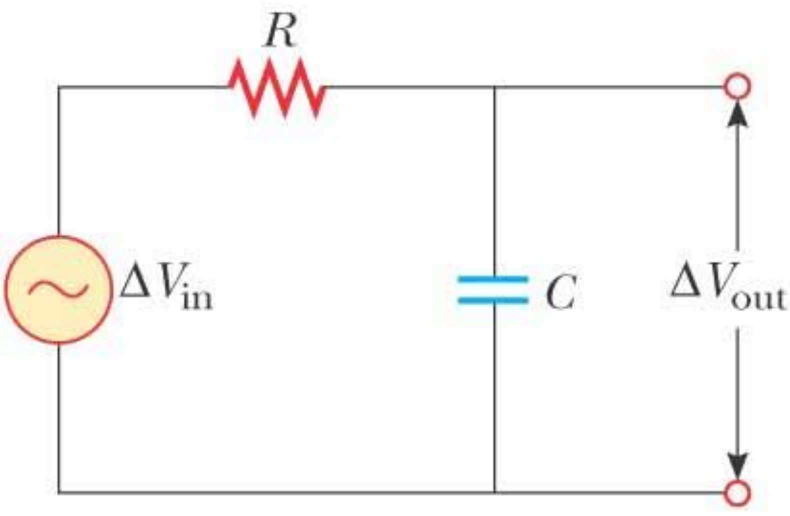
C
ΔV_{in}
R
ΔV_{out}
$\Delta V_{out}/\Delta V_{in}$
1
log ω
(a)
(b)



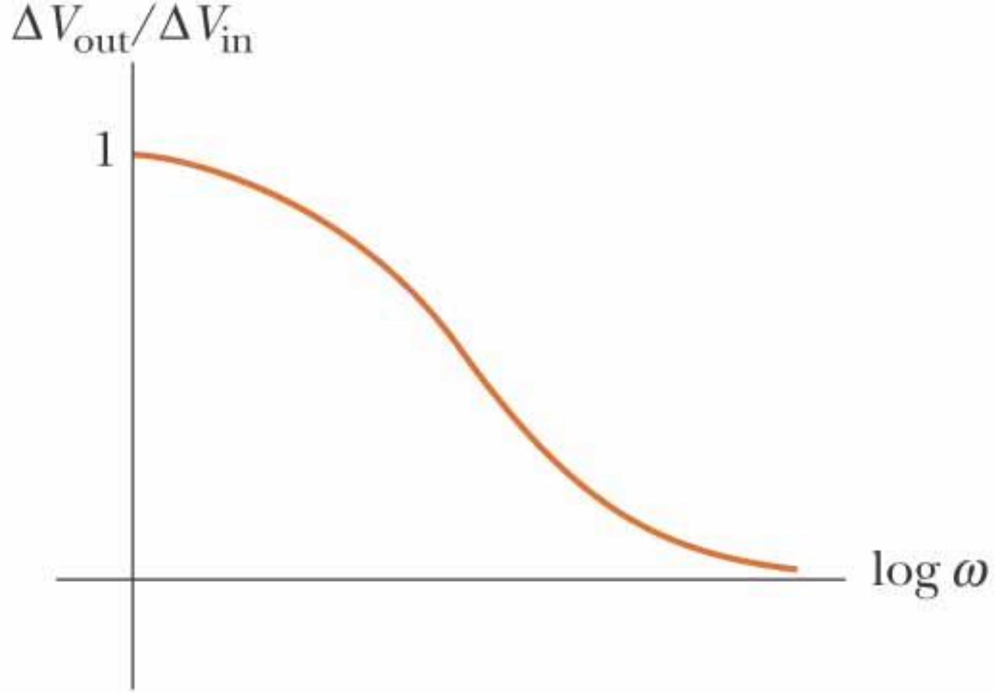
(a)



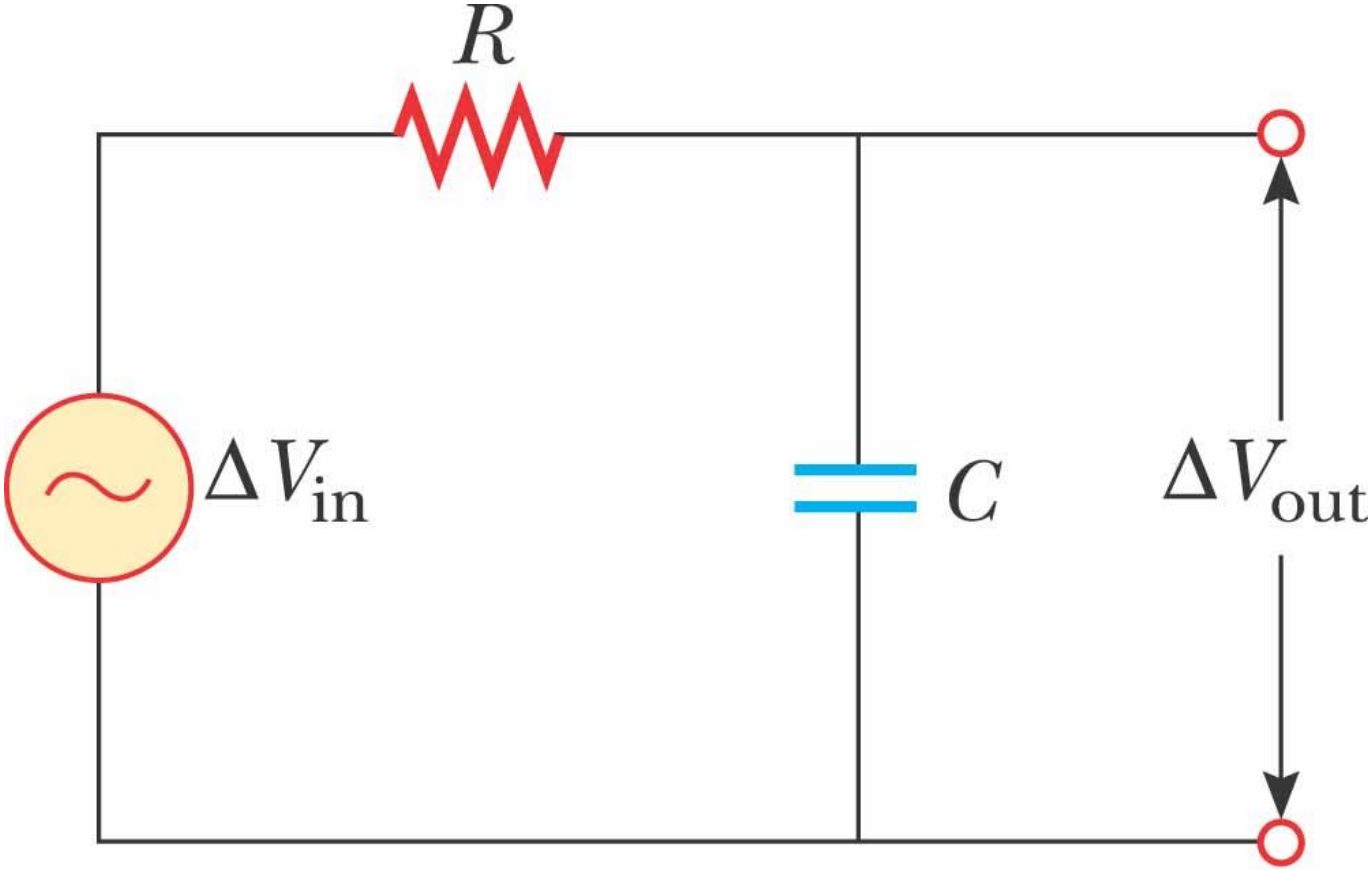
(b)



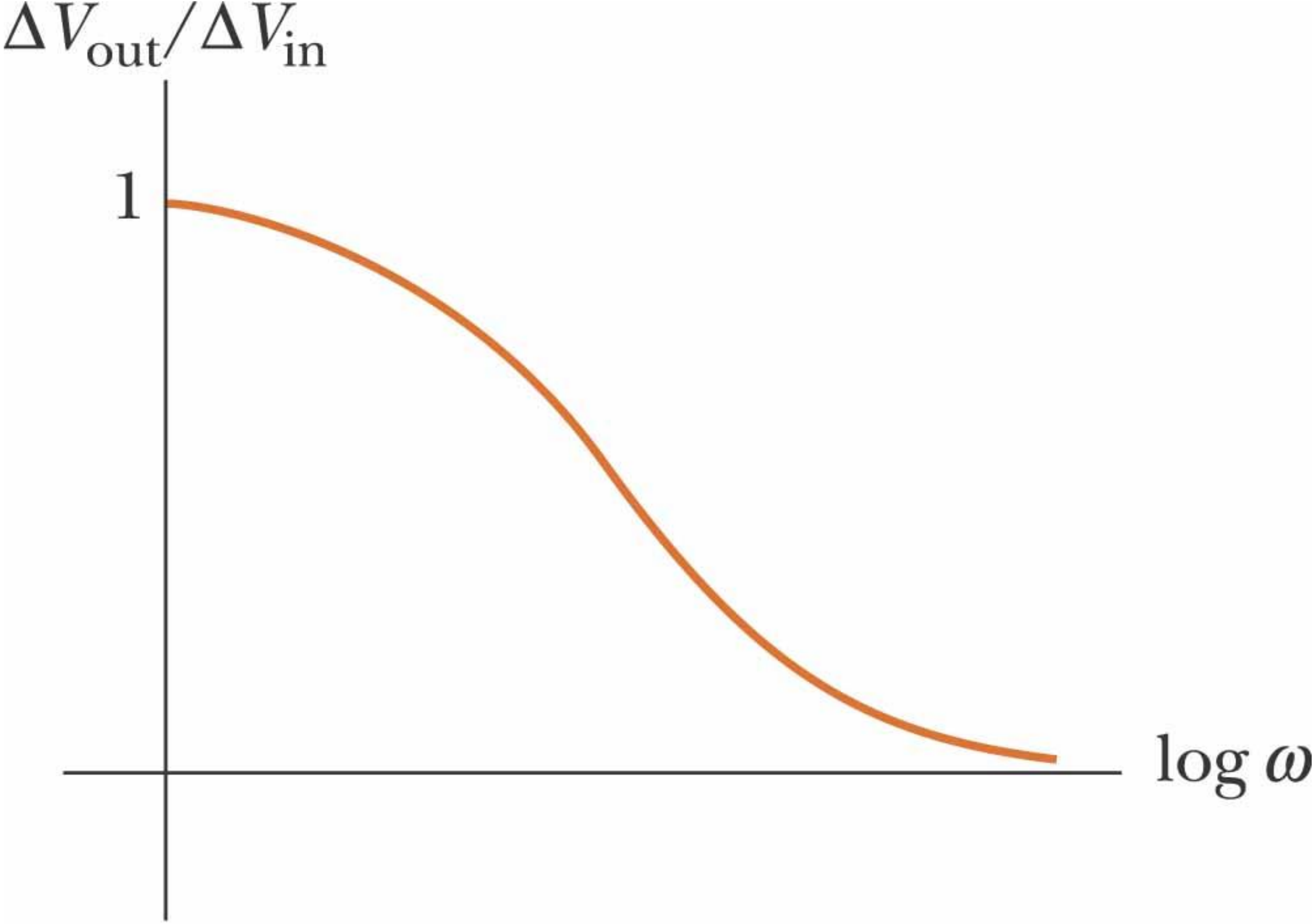
(a)



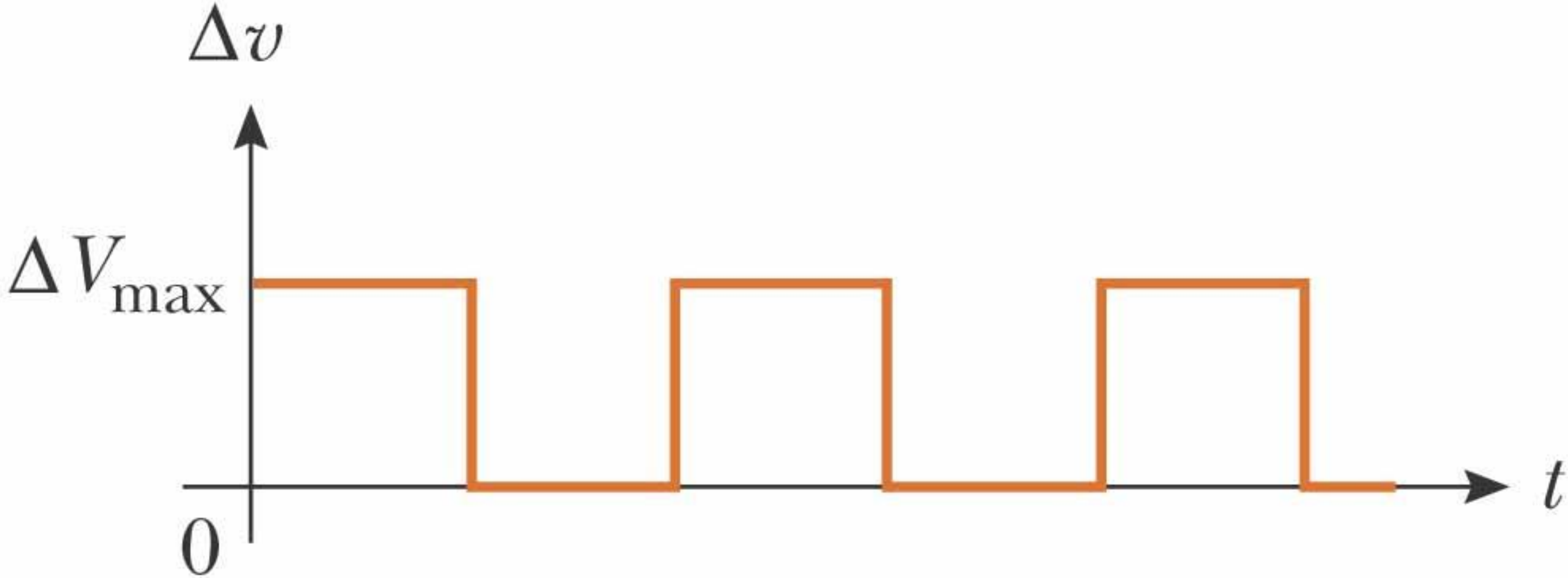
(b)

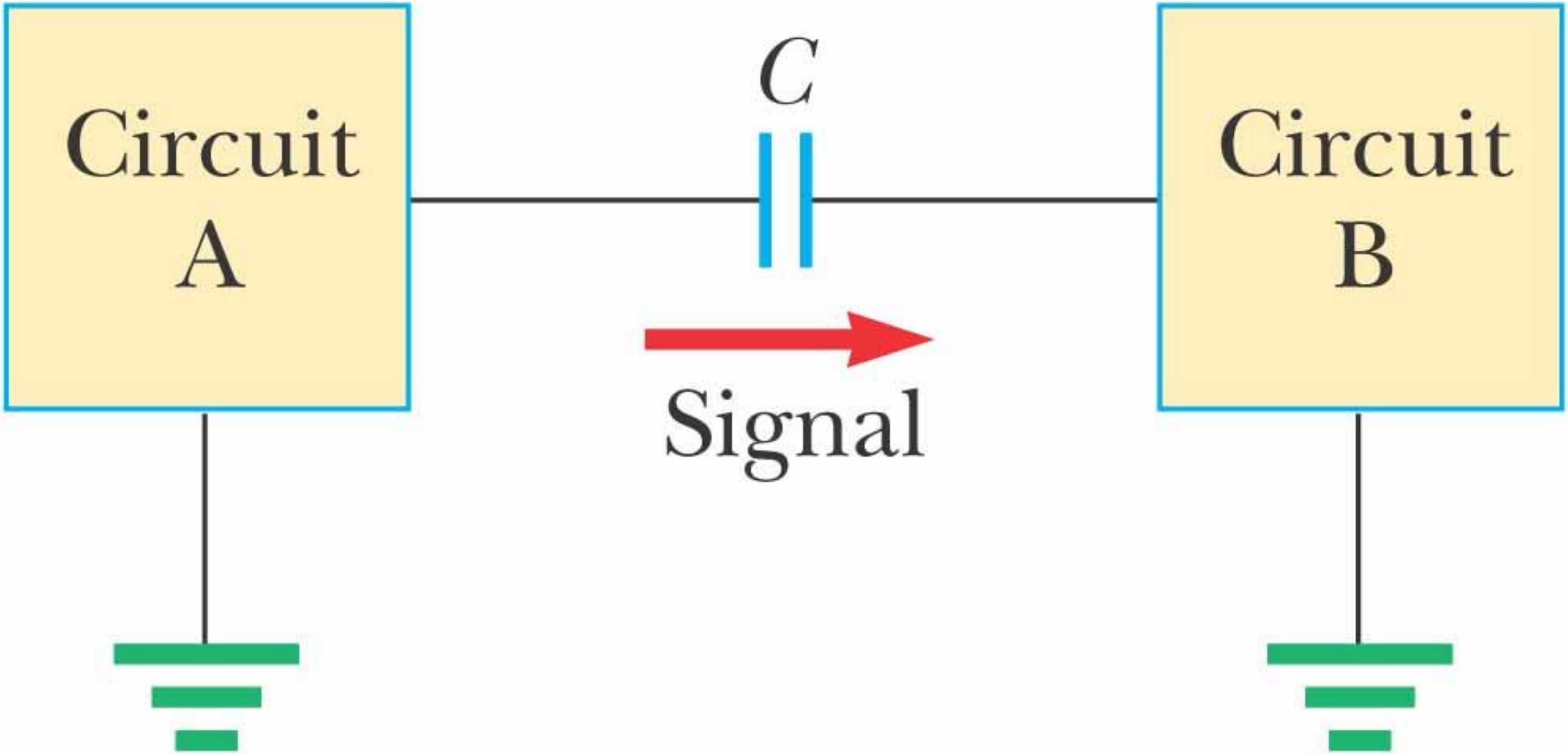


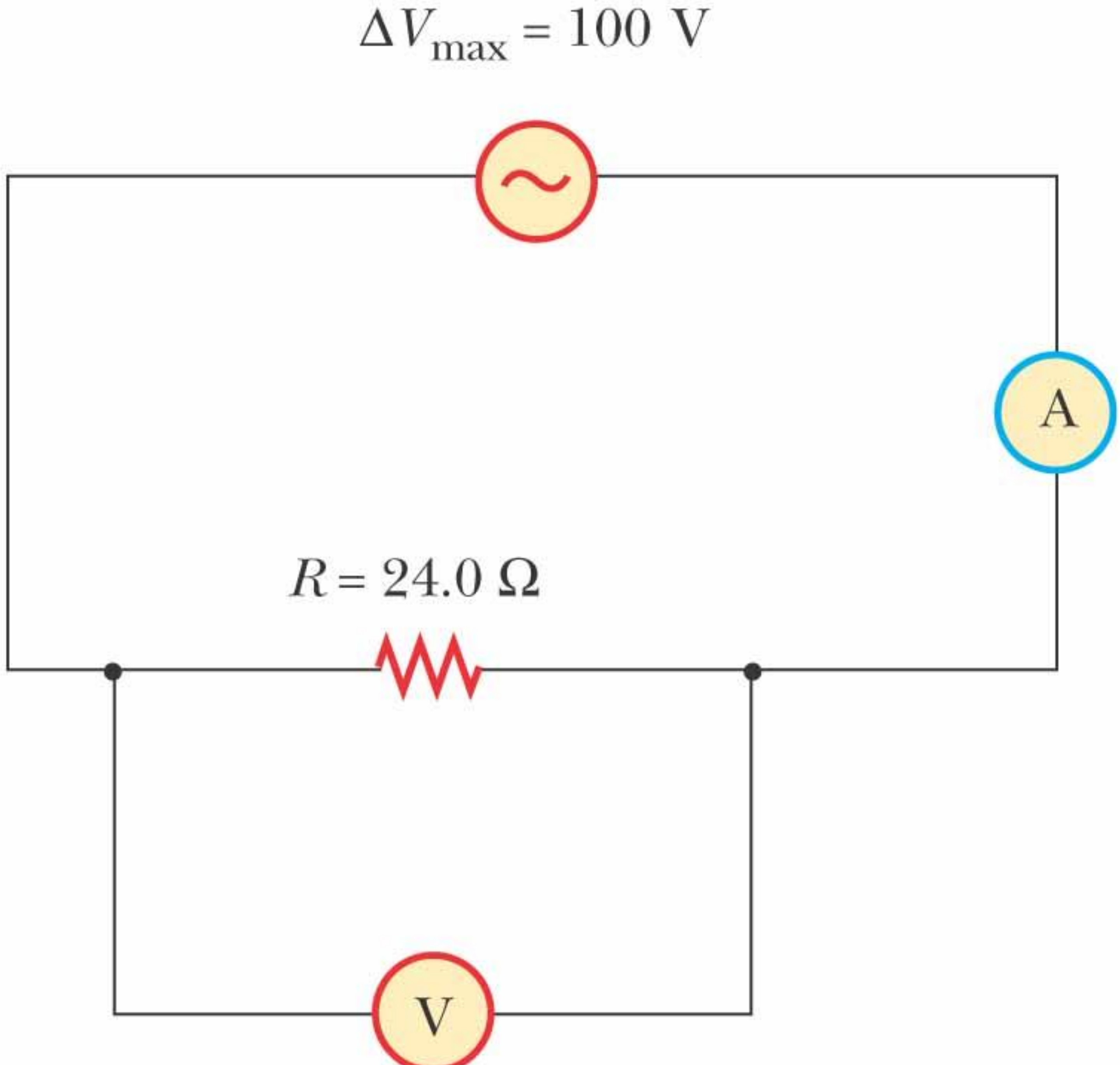
(a)



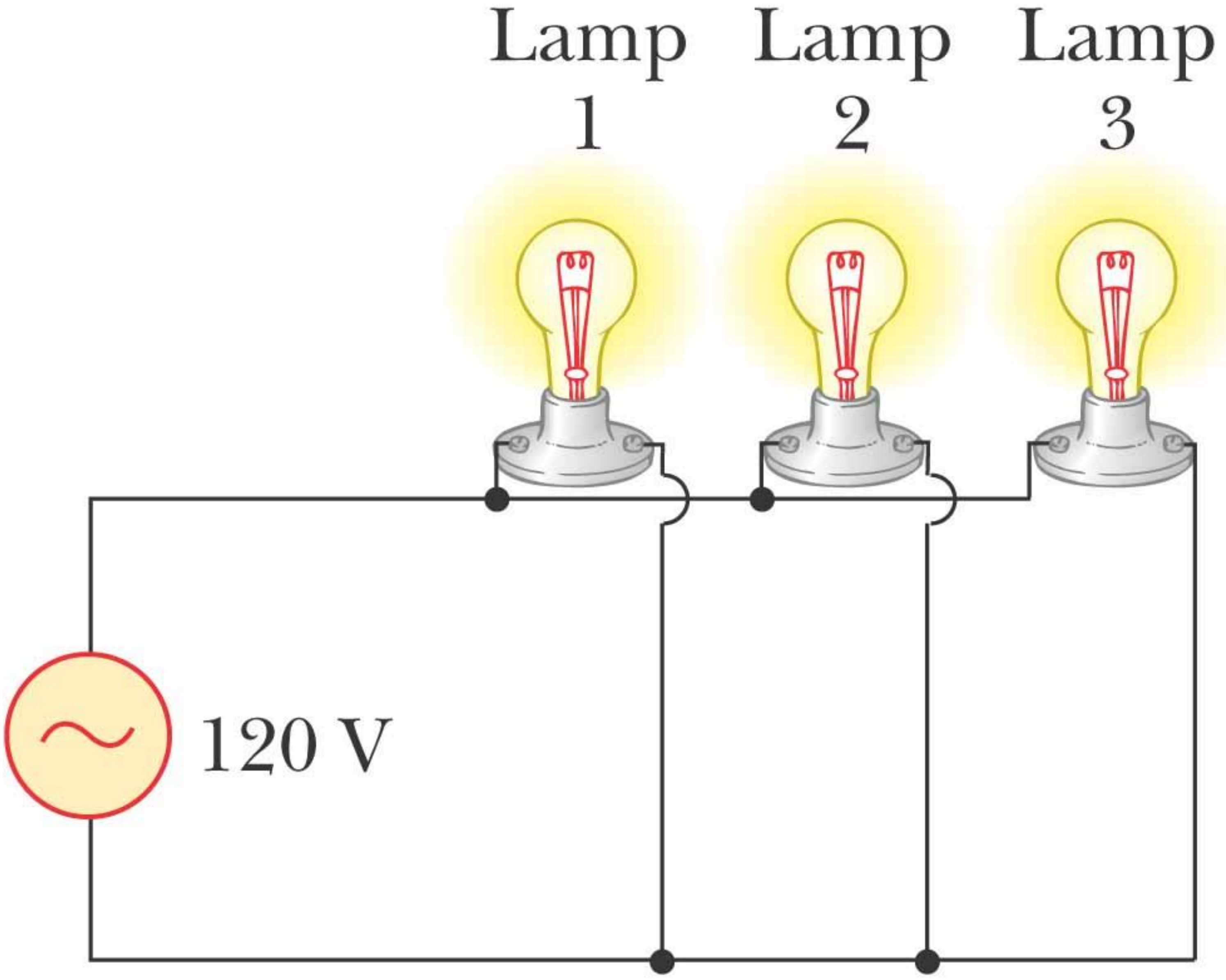
(b)

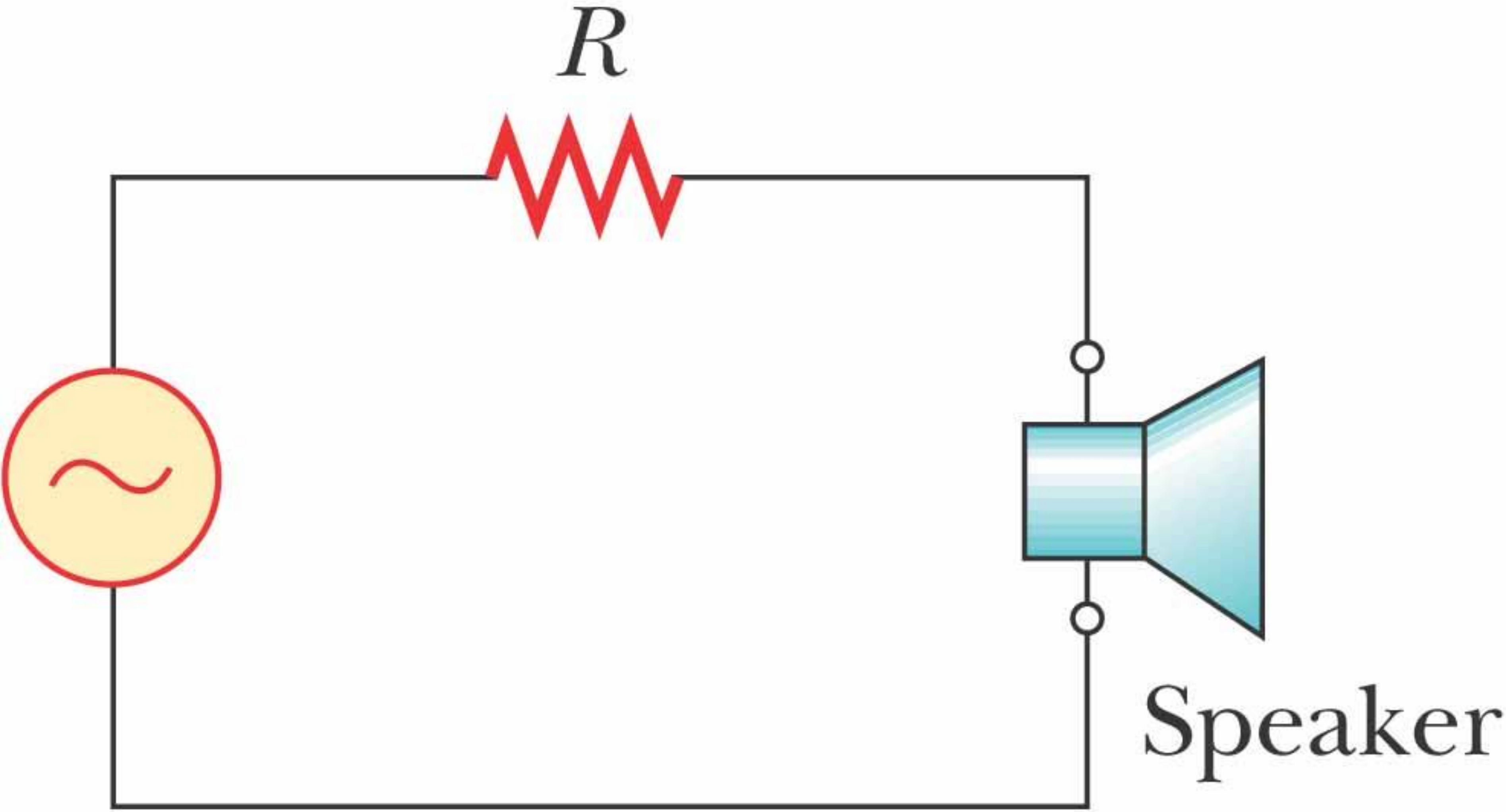

Δv
$\Delta V_{\max}$
0
t


Circuit
A
C
Signal
Circuit
B

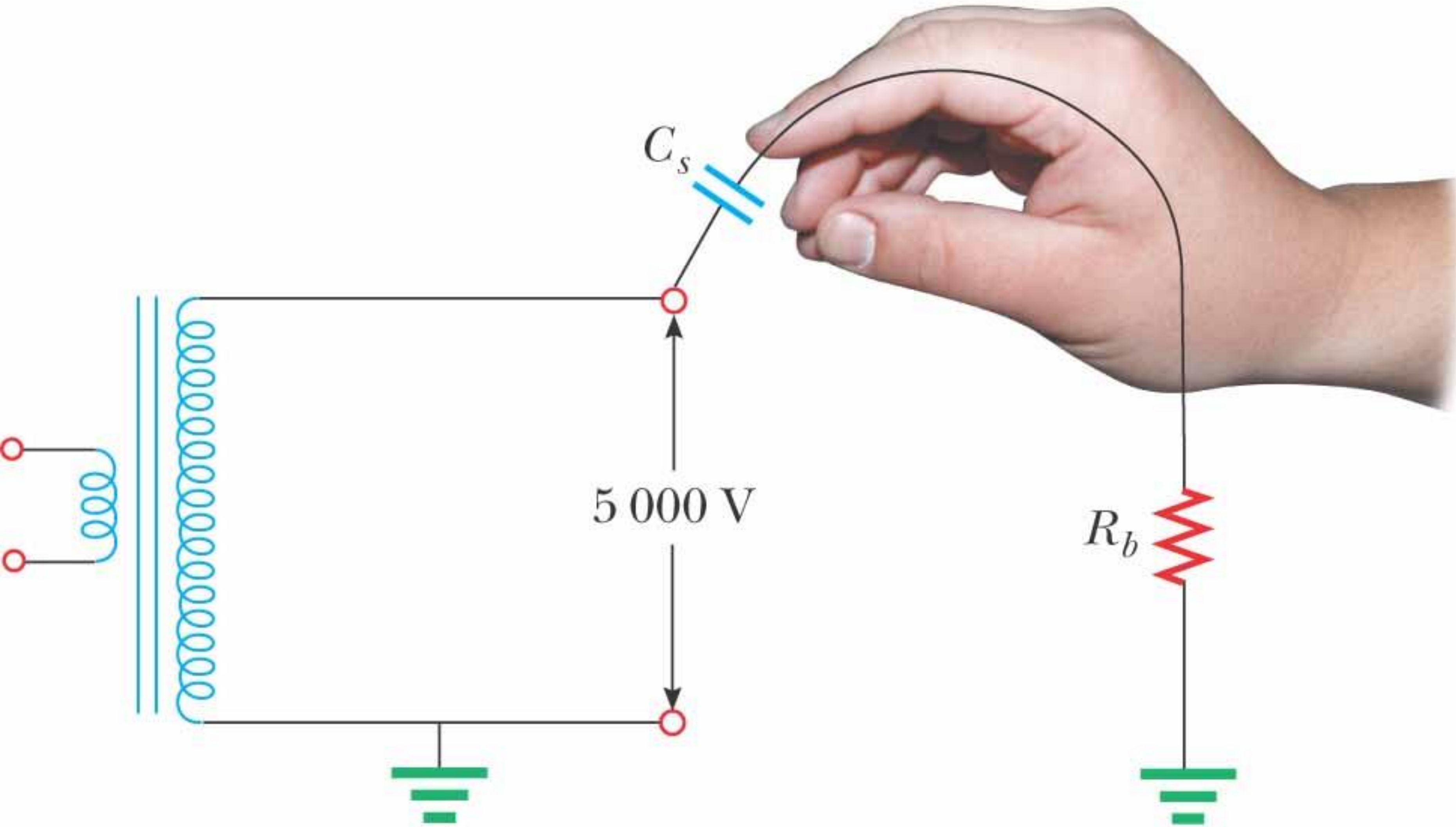


Slide 62

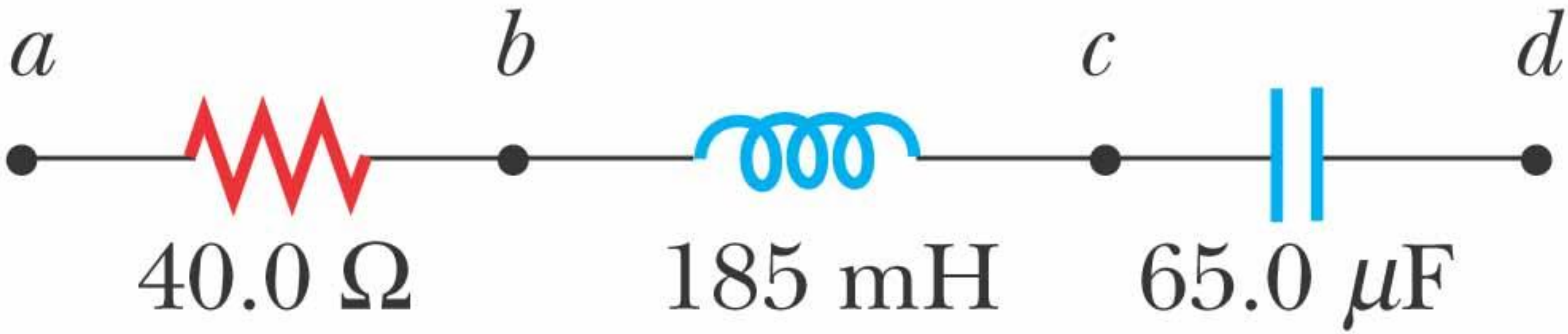

Lamp 1
Lamp 2
Lamp 3
120 V

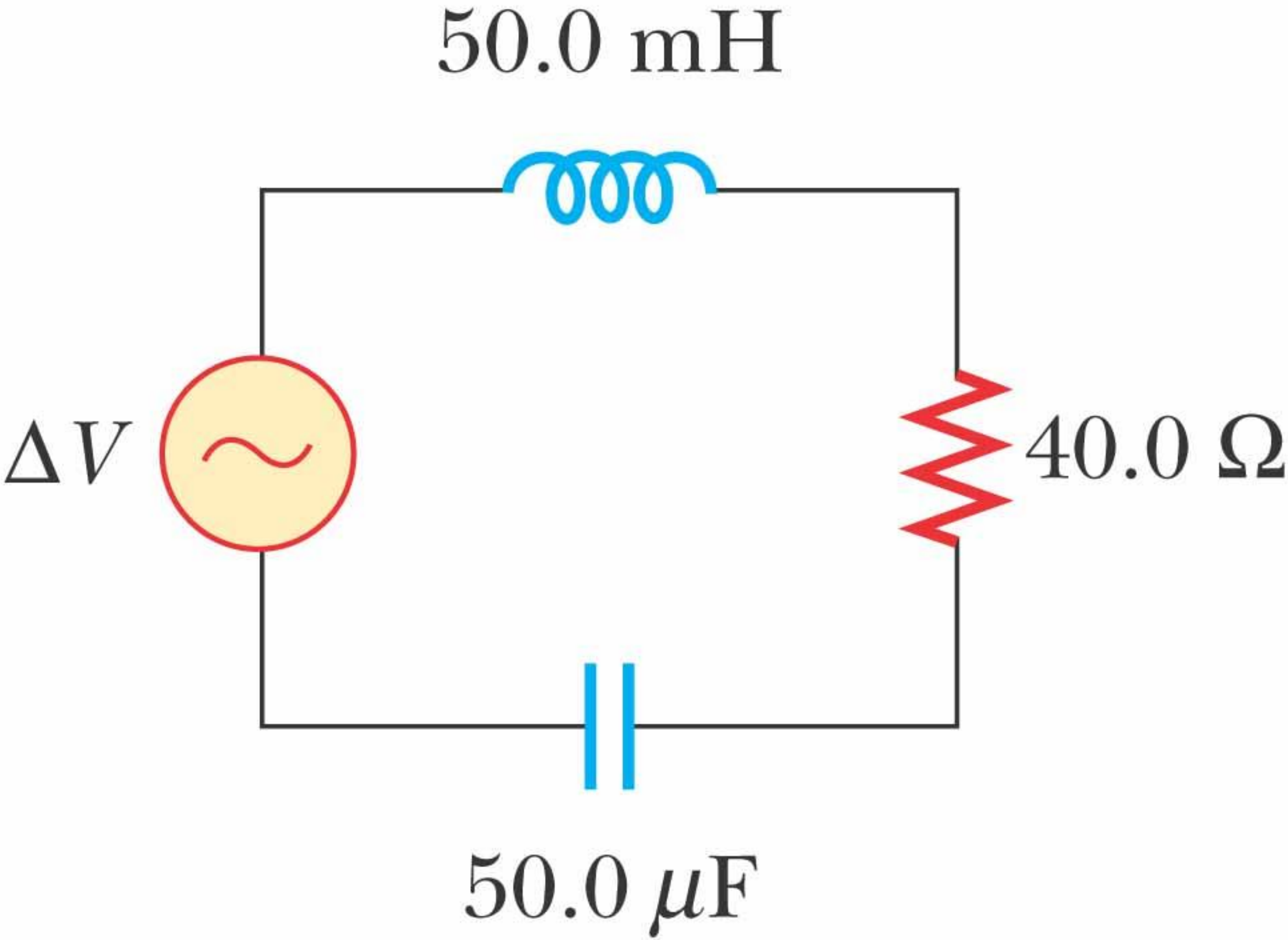


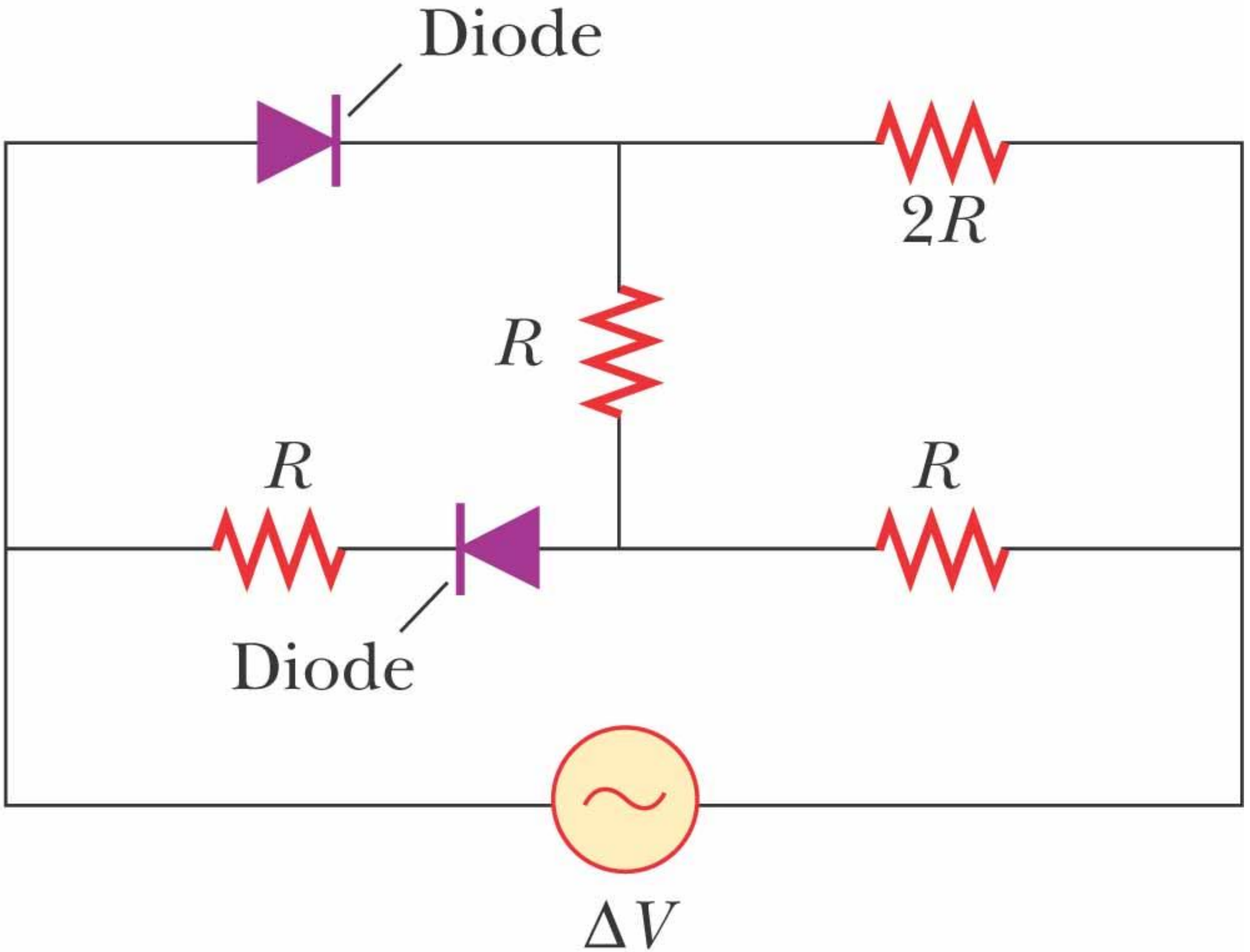
R
Speaker



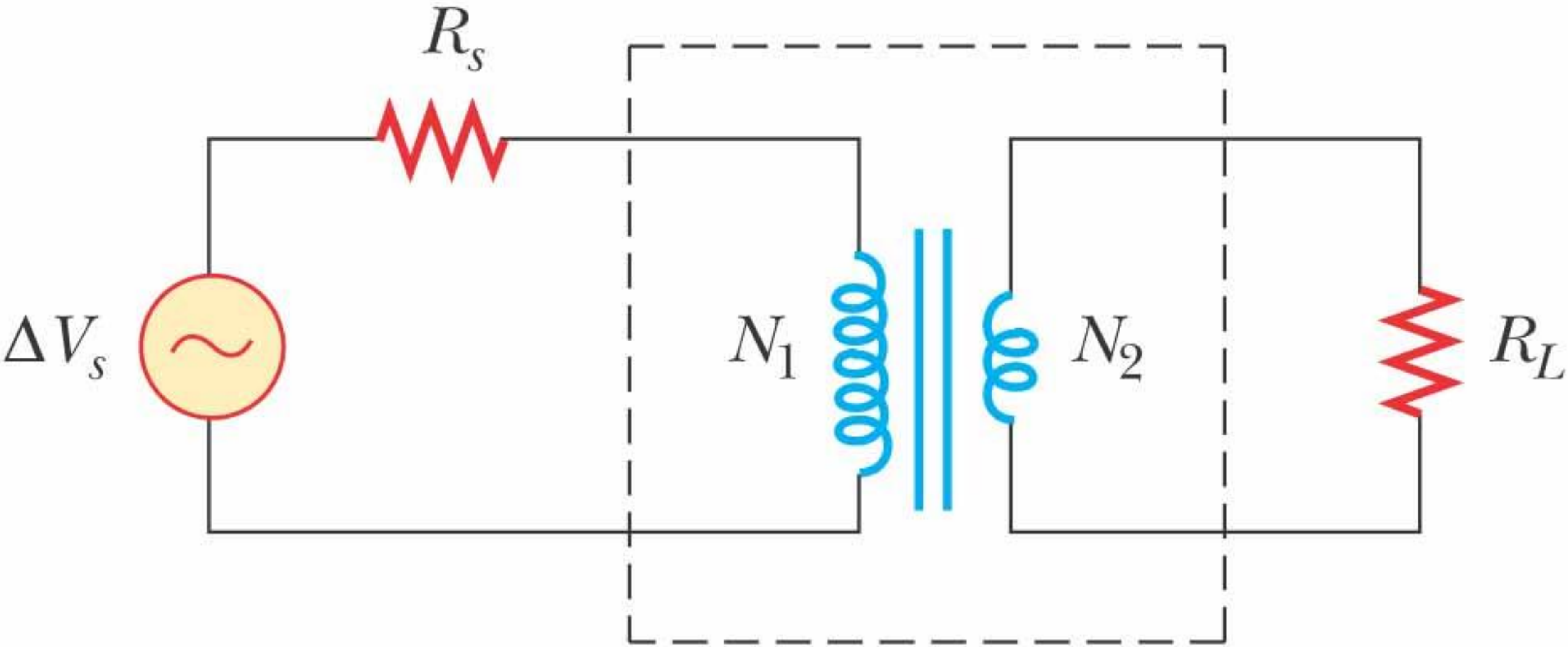
C_s
5 000 V
R_b

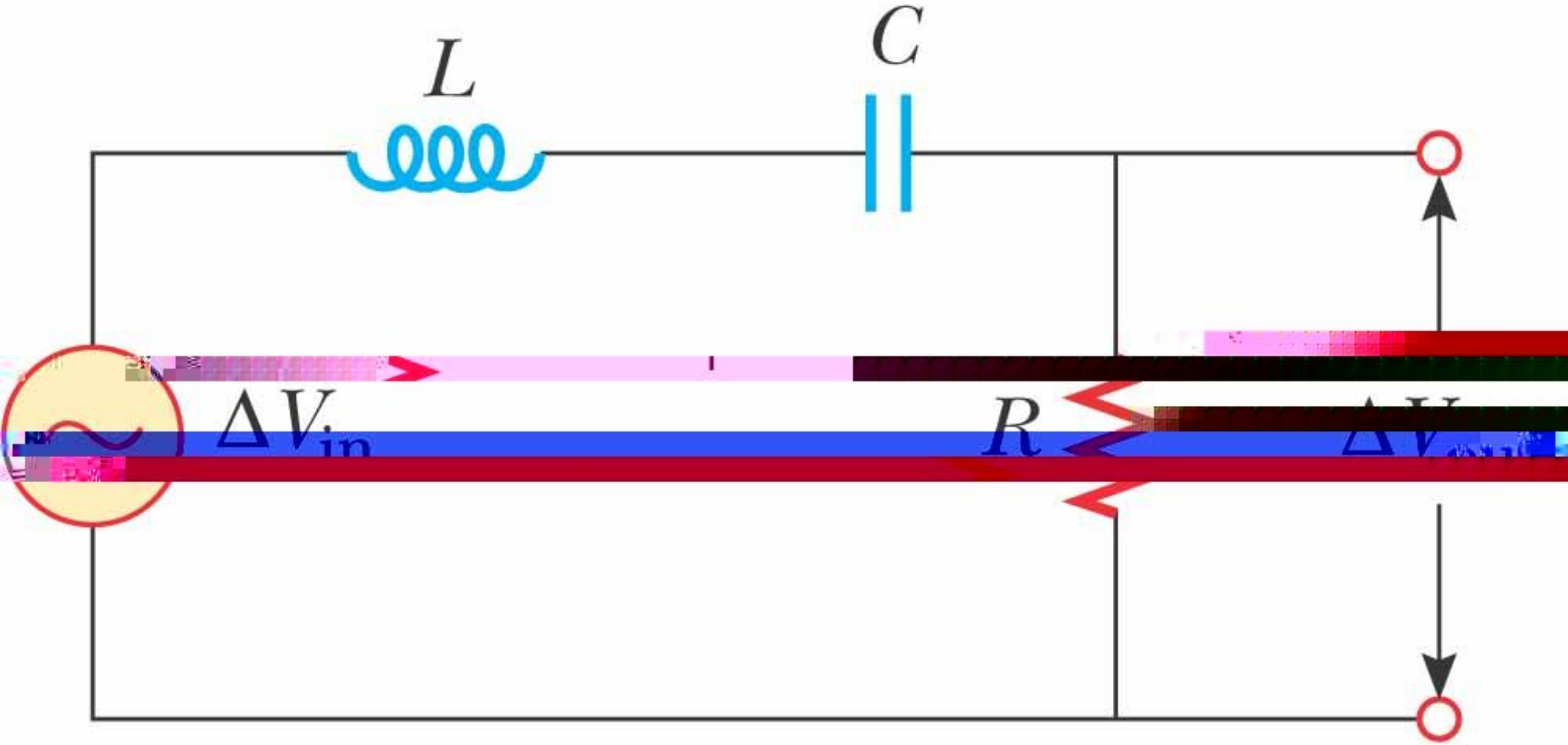

a
b
c
d
40.0 Ω
185 mH
65.0 μF

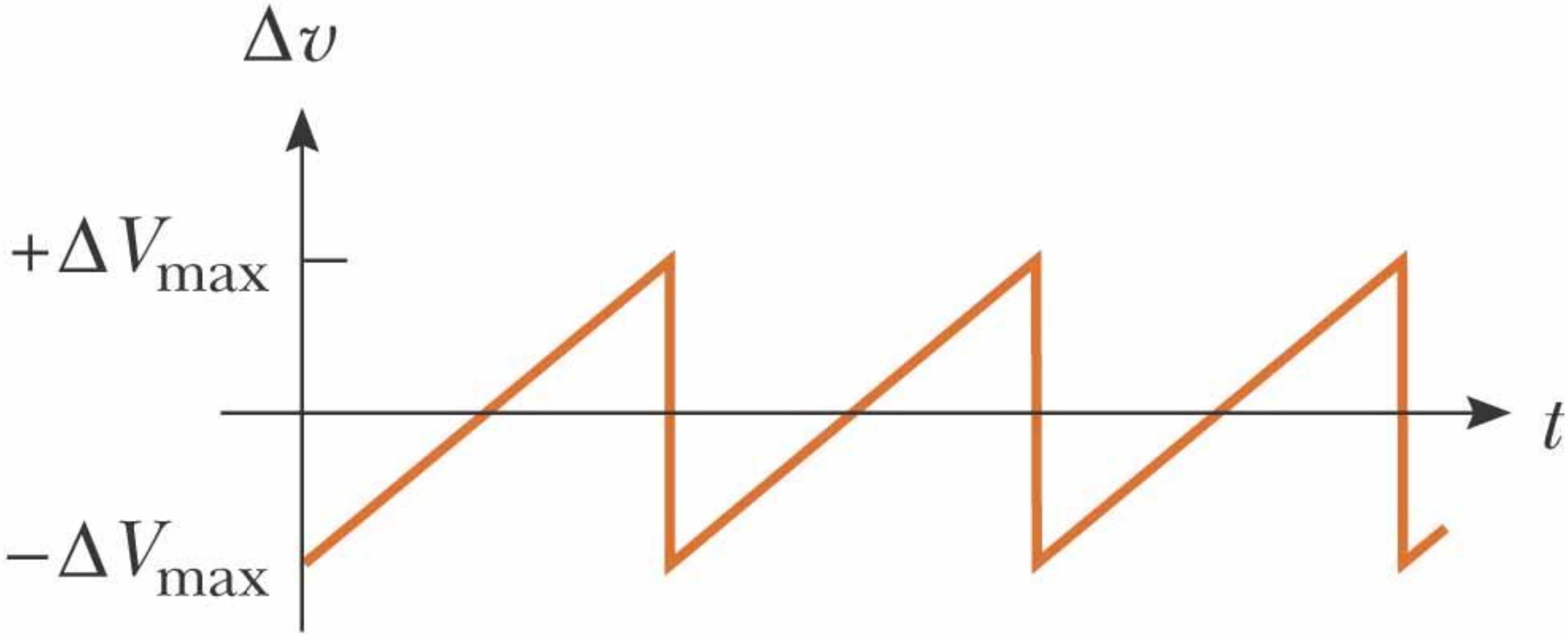

50.0 mH
ΔV
40.0 Ω
50.0 μF

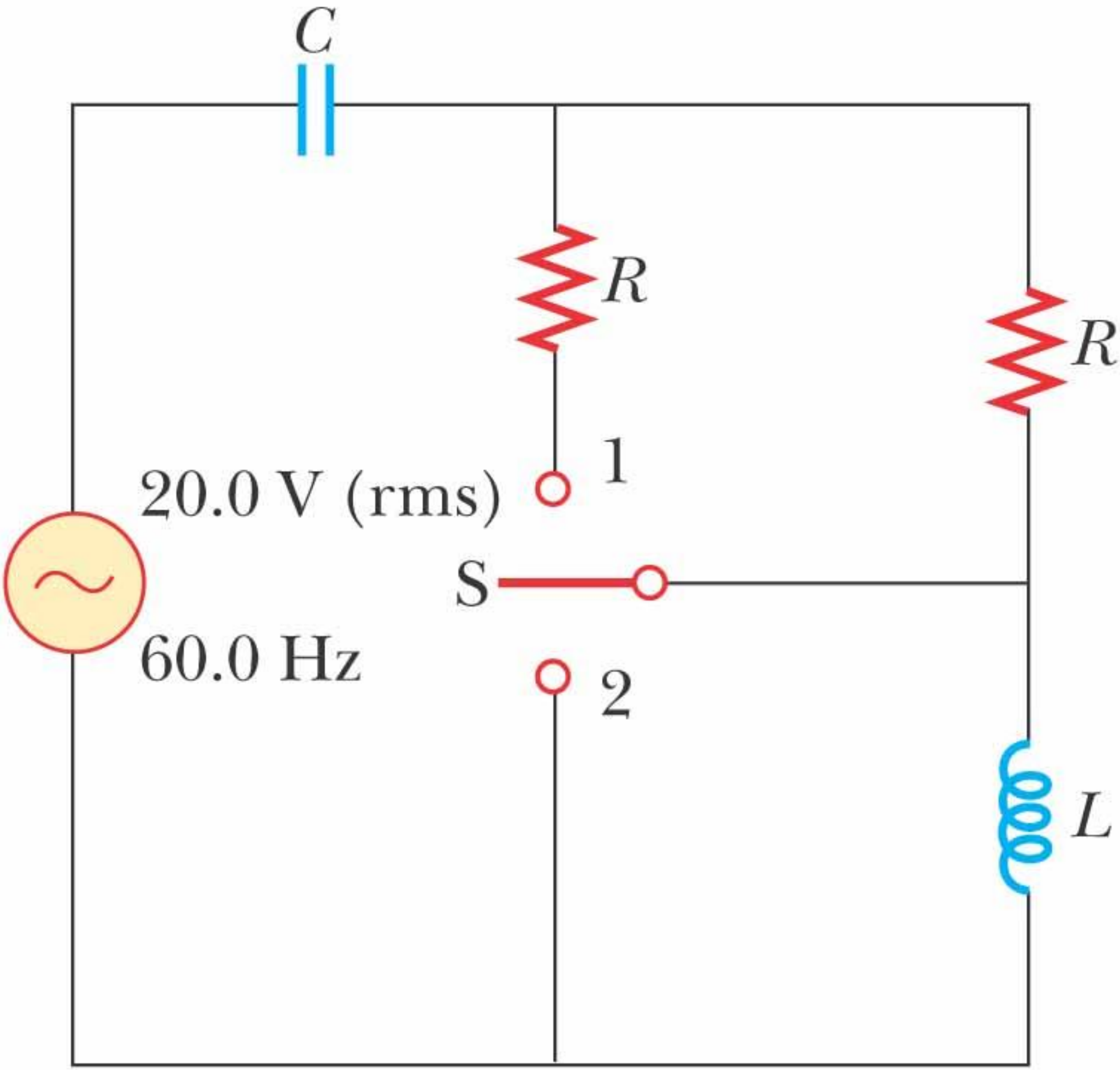


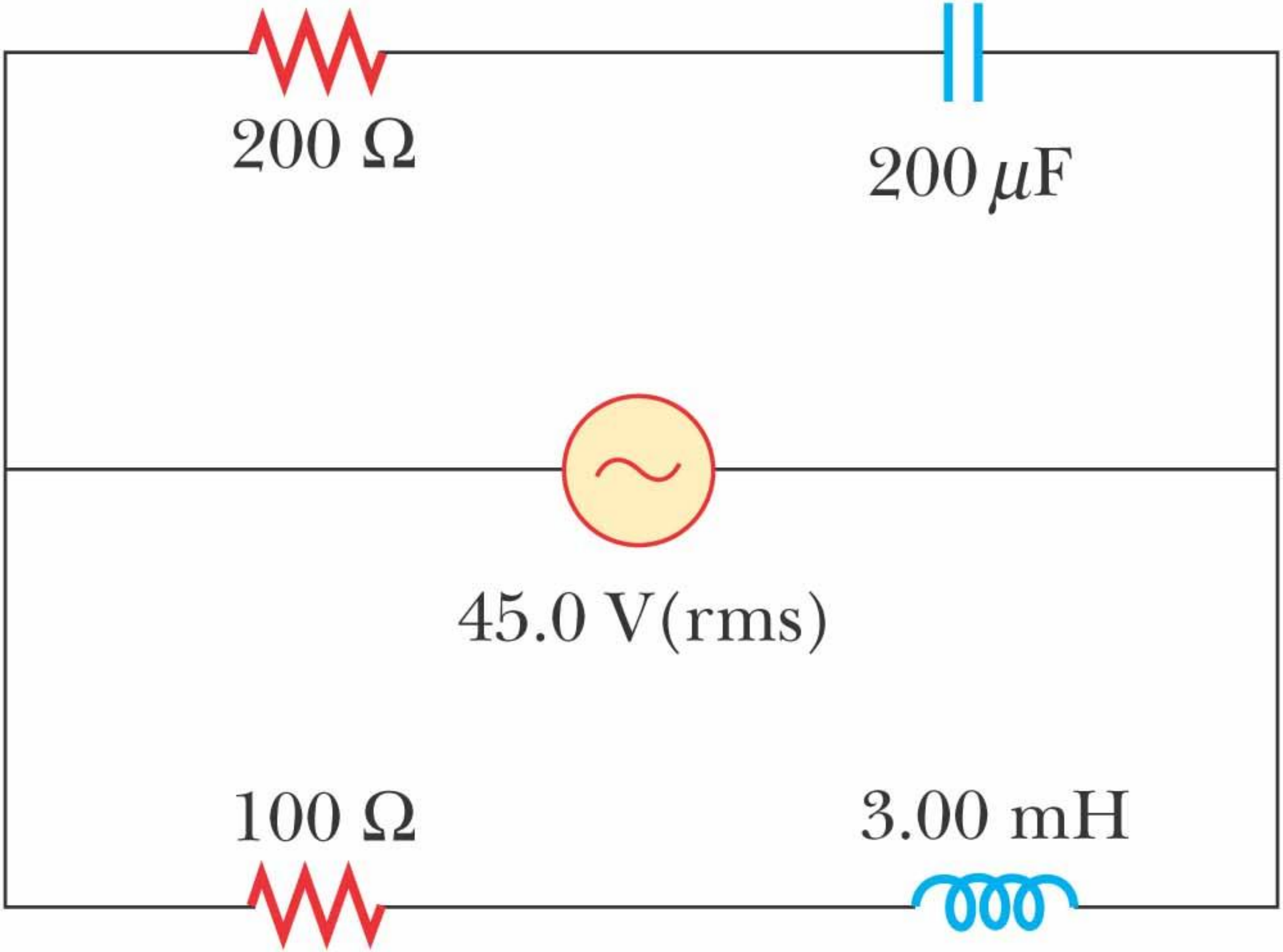
Diode
2R
R
R
R
Diode
ΔV

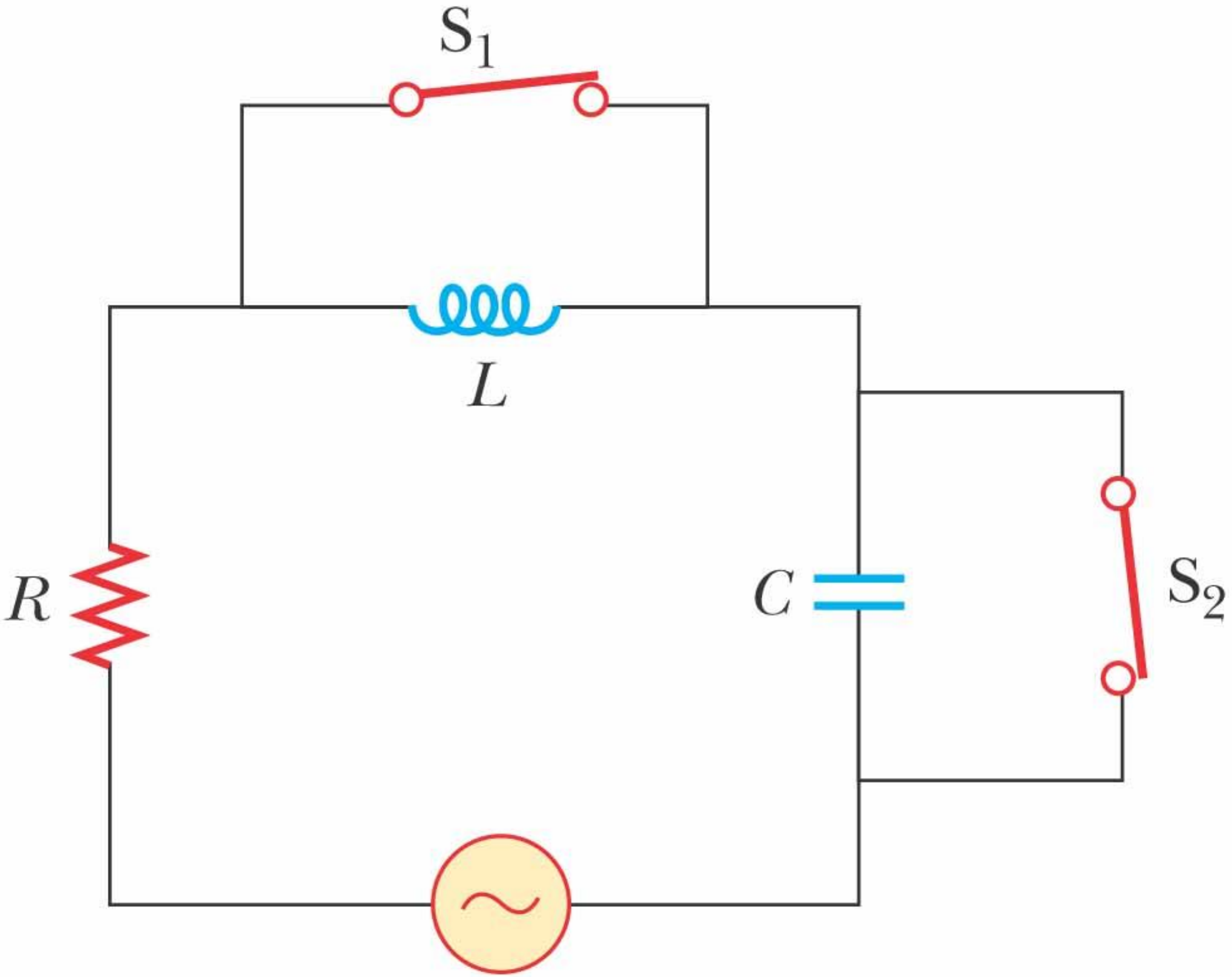

R_s
ΔV_s
N_1
N_2
R_L


L
C
ΔV_in
R

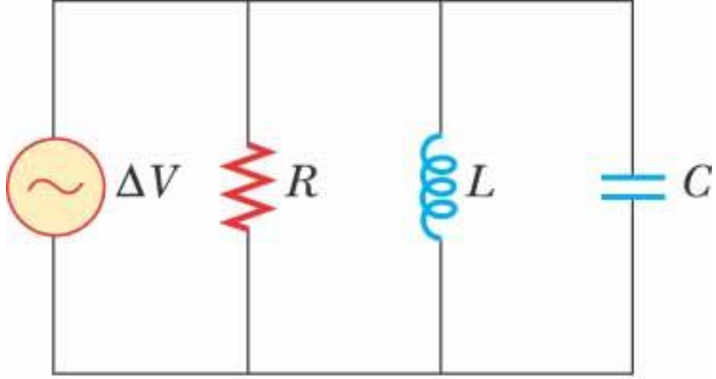

Δv
$+\Delta V_{\max}$
$-\Delta V_{\max}$
t


C
R
R
1
20.0 V (rms)
S
60.0 Hz
2
L

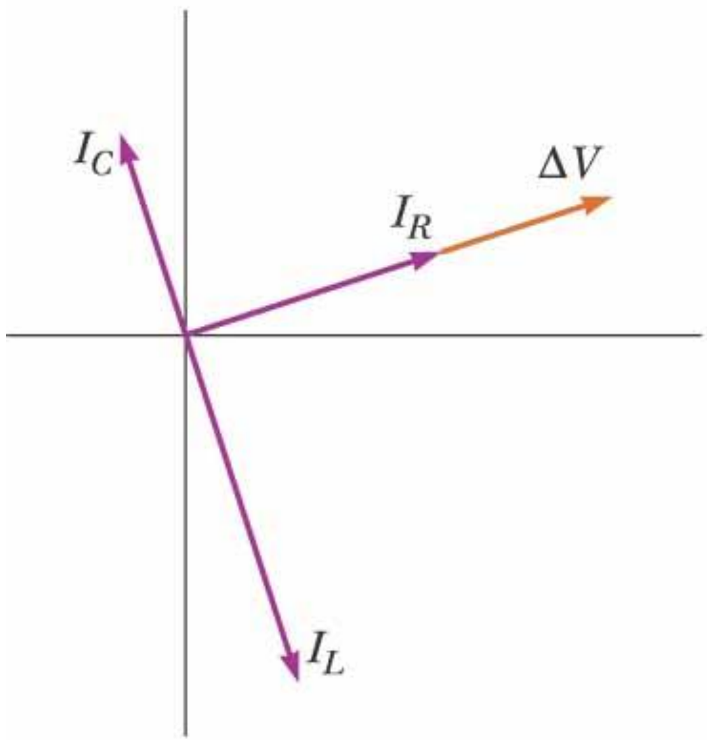

200 Ω
200 μF
45.0 V(rms)
100 Ω
3.00 mH



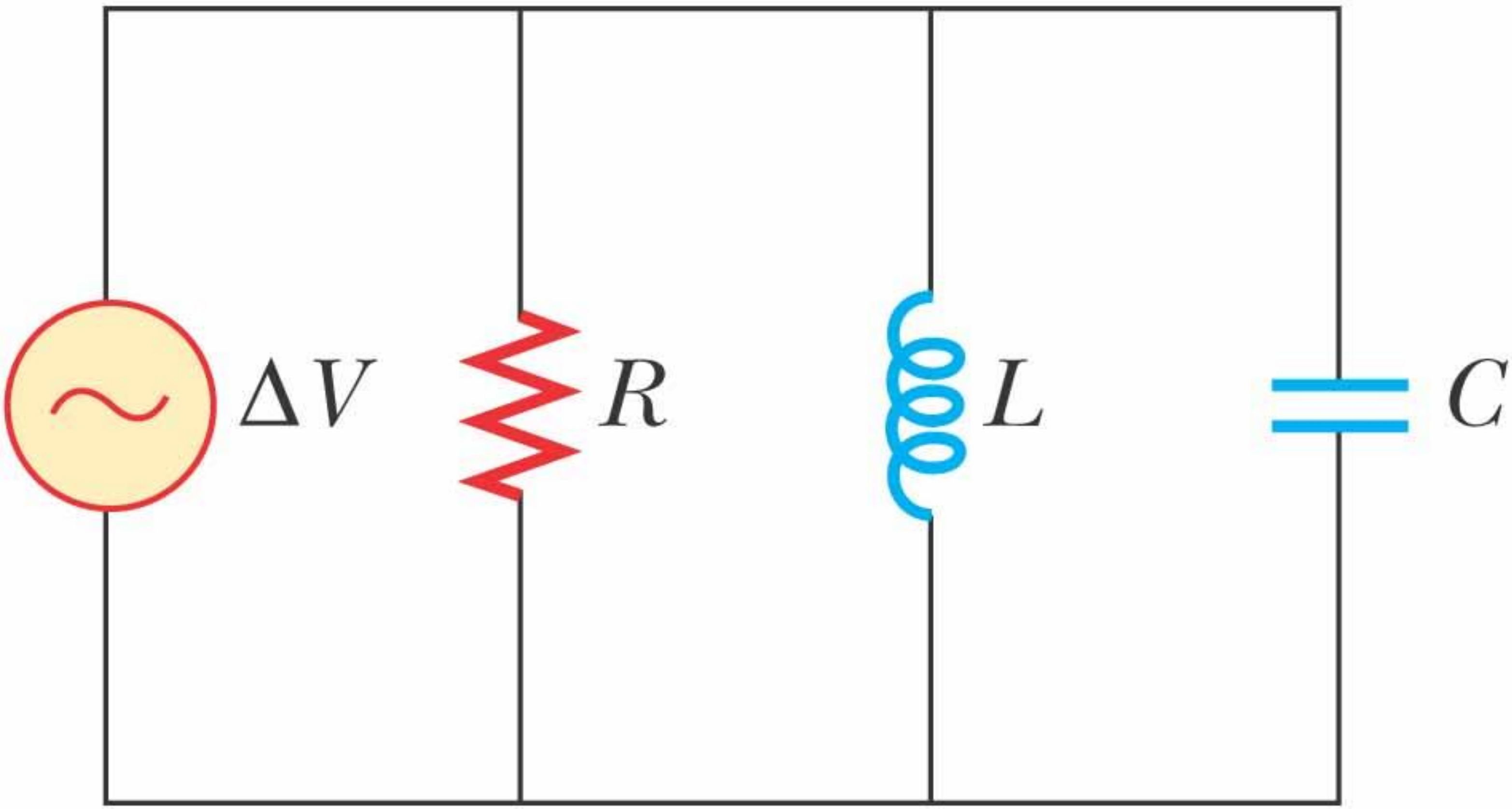
$$\Delta v(t) = \Delta V_{max} \cos \omega t$$



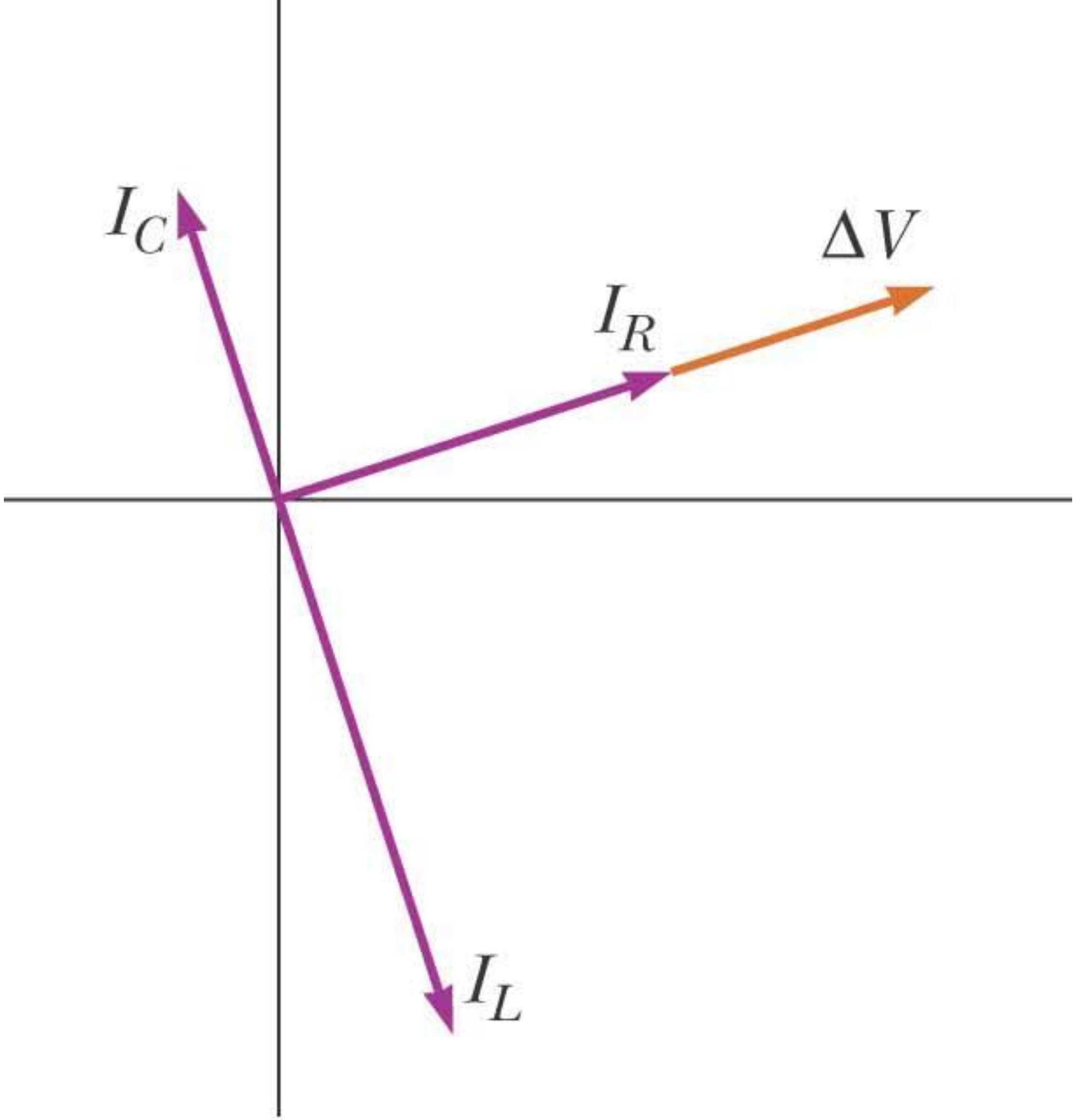
(a)



(b)



(a)



(b)

Link for more explanations

1 https://www.youtube.com/watch?v=a2tmHmIQ3hw&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=29

2. https://www.youtube.com/watch?v=qyKEw9X-yHQ&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=136

3. https://www.youtube.com/watch?v=IST5IV-fPtQ&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=143

4. https://www.youtube.com/watch?v=kngph7wjuBk&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=151

5. https://www.youtube.com/watch?v=49ZE1DtTQ-M&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=160

6. https://www.youtube.com/watch?v=ZJ8zD8m-B1Q&list=PLBlnK6fEyqRgLR-hMp7wem-bdVN1iEhsh&index=169

7. https://youtu.be/eQNMh8h9wbA