Chapter 31

Alternating Current

PowerPoint® Lectures for
University Physics, Thirteenth Edition
– Hugh D. Young and Roger A. Freedman

Lectures by Wayne Anderson

Goals for Chapter 31

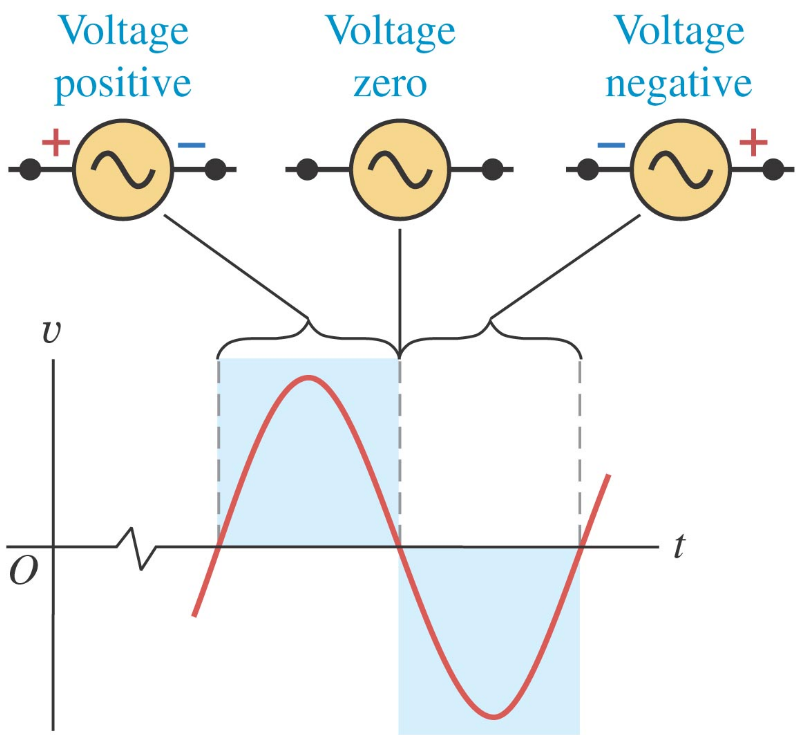
- To use phasors to describe sinusoidally varying quantities
- To use reactance to describe voltage in a circuit
- To analyze an *L-R-C* series circuit
- To determine power in ac circuits
- To see how an *L-R-C* circuit responds to frequency
- To learn how transformers work

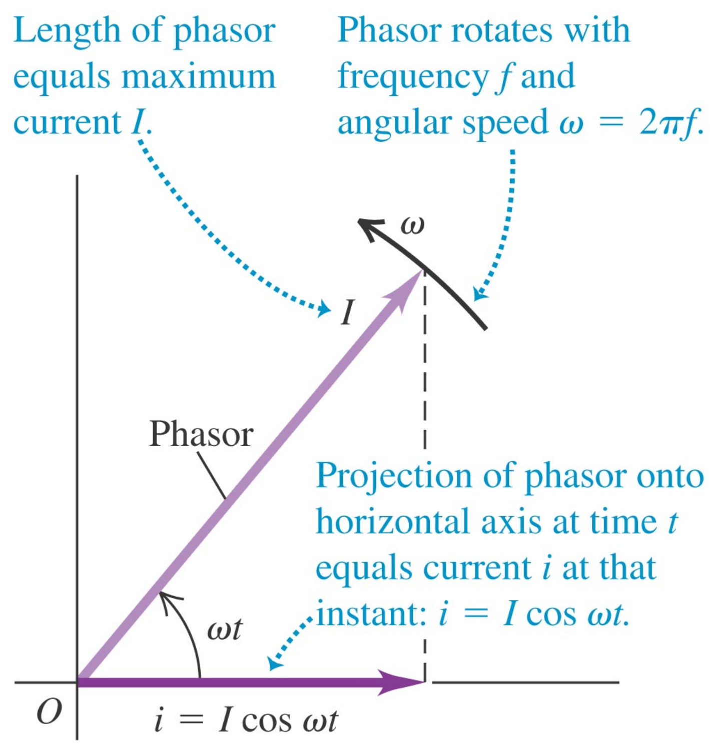
Introduction

- How does a radio tune to a particular station?
- How are ac circuits different from dc circuits?
- We shall see how resistors, capacitors, and inductors behave with a sinusoidally varying voltage source.

Phasors and alternating currents

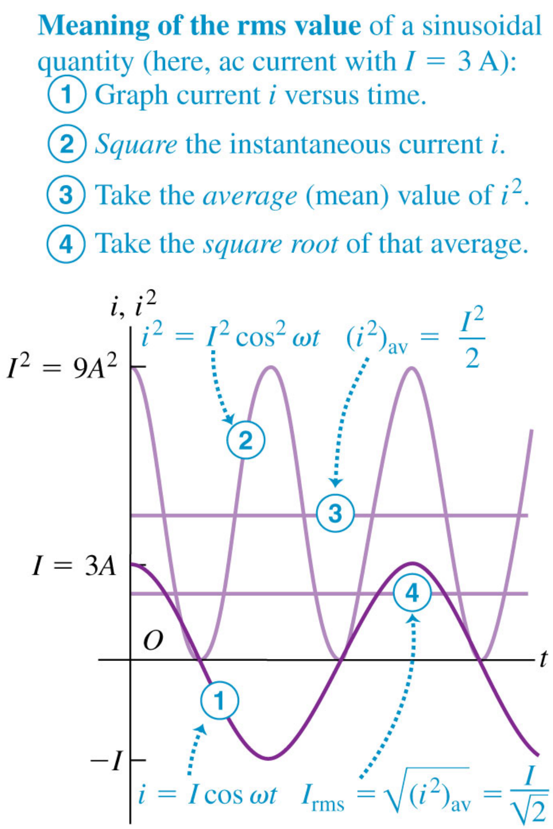
- Follow the text discussion of alternating current and phasors using Figures 31.1 (which shows ac voltage) and 31.2 (which shows a phasor diagram) below.

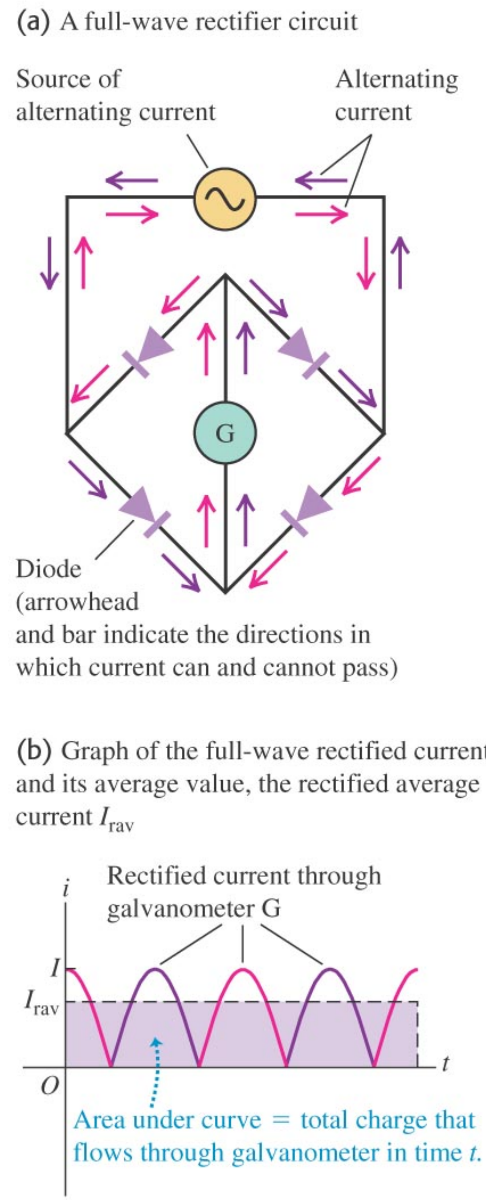




Root-mean-square values

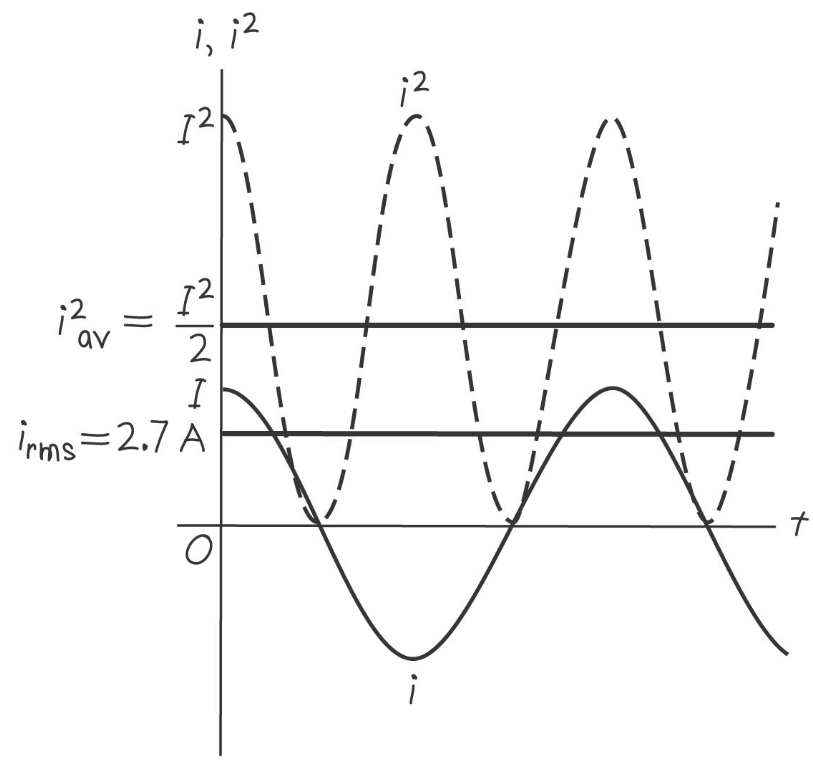
- Follow the text discussion of rectified alternating current, rms current, and rms voltage. Use Figures 31.3 (right) and 31.4 (below).





Current in a personal computer

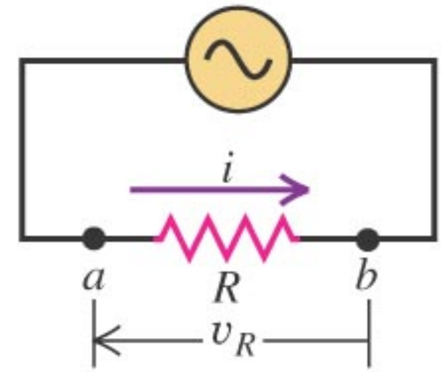
- Follow Example 31.1 using Figure 31.6 below.



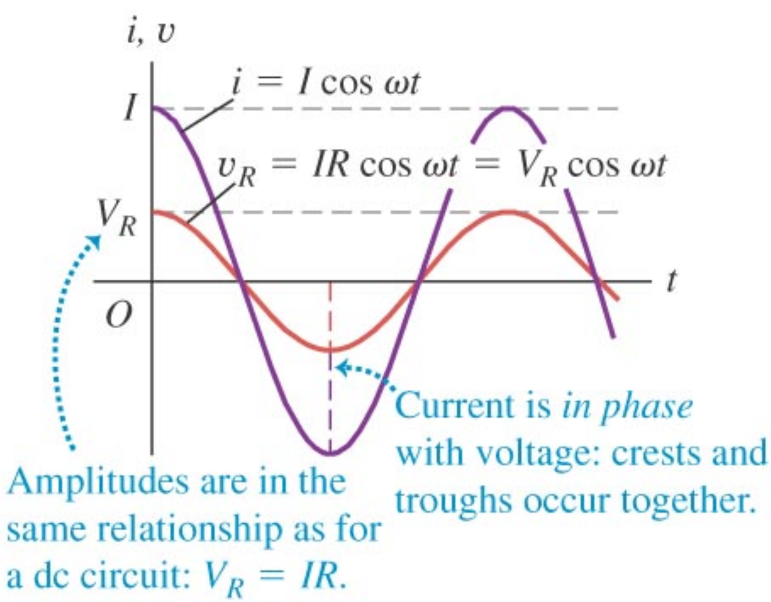
Resistor in an ac circuit

- Ohm's Law gives the voltage amplitude across a resistor: $V_R = IR$.
- Figure 31.7 shows the circuit, the current and voltage as functions of time, and a phasor.

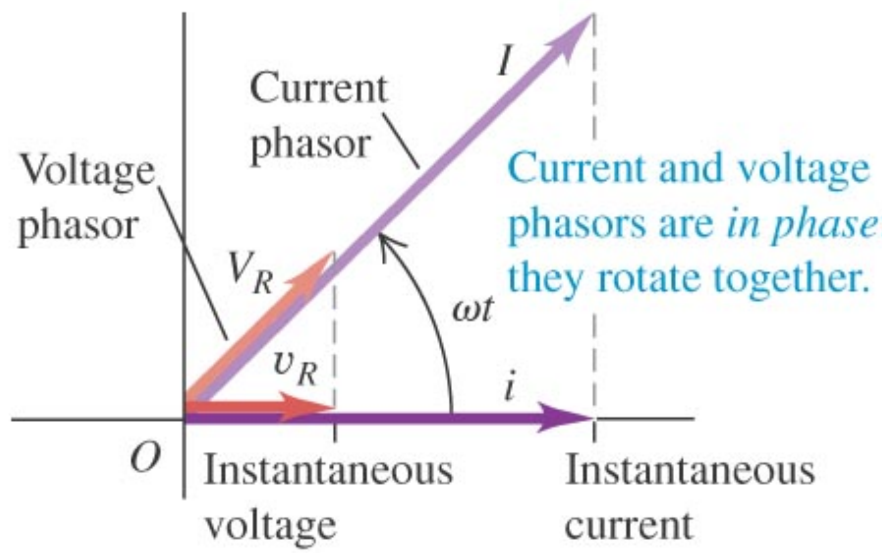
(a) Circuit with ac source and resistor



(b) Graphs of current and voltage versus time

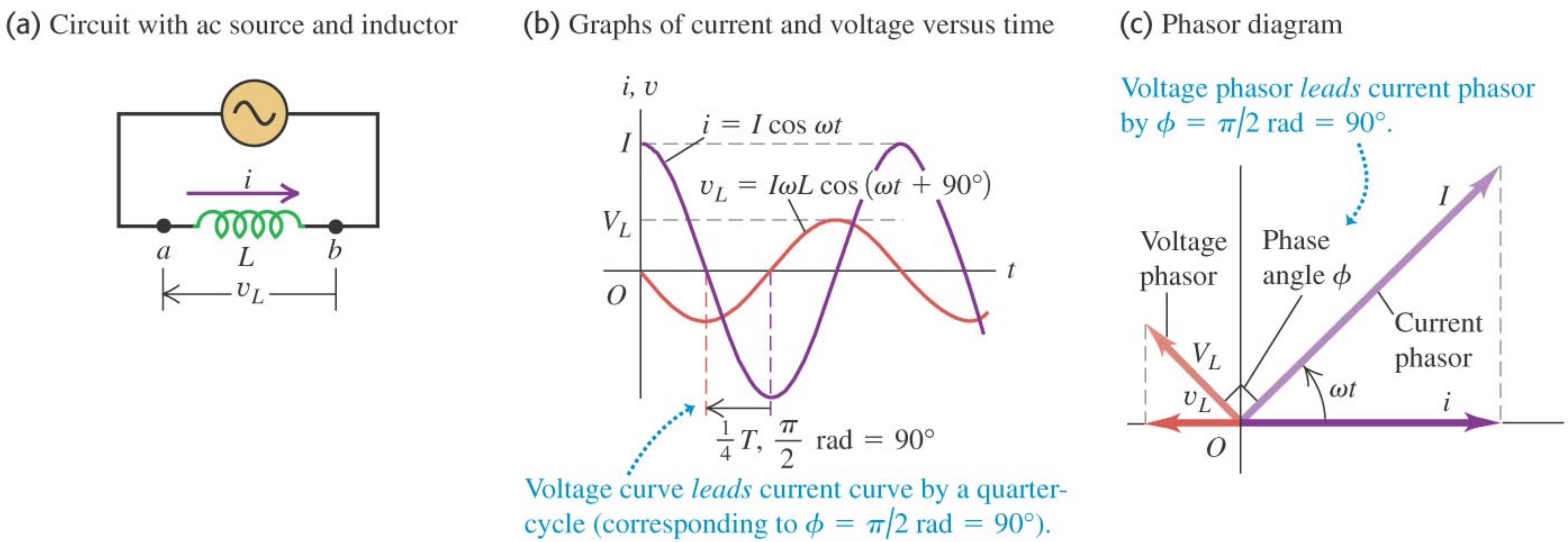


(c) Phasor diagram



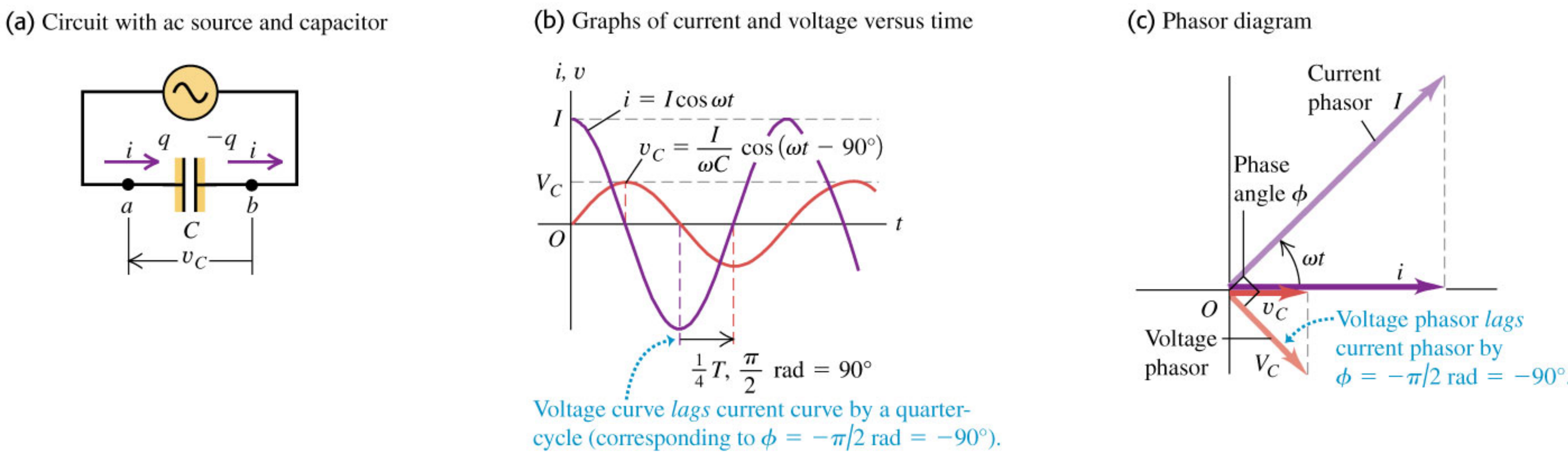
Inductor in an ac circuit

- Follow the text analysis of an inductor in an ac circuit using Figure 31.8 below. The voltage amplitude across the inductor is $V_L = IX_L$.
- Follow Example 31.2.



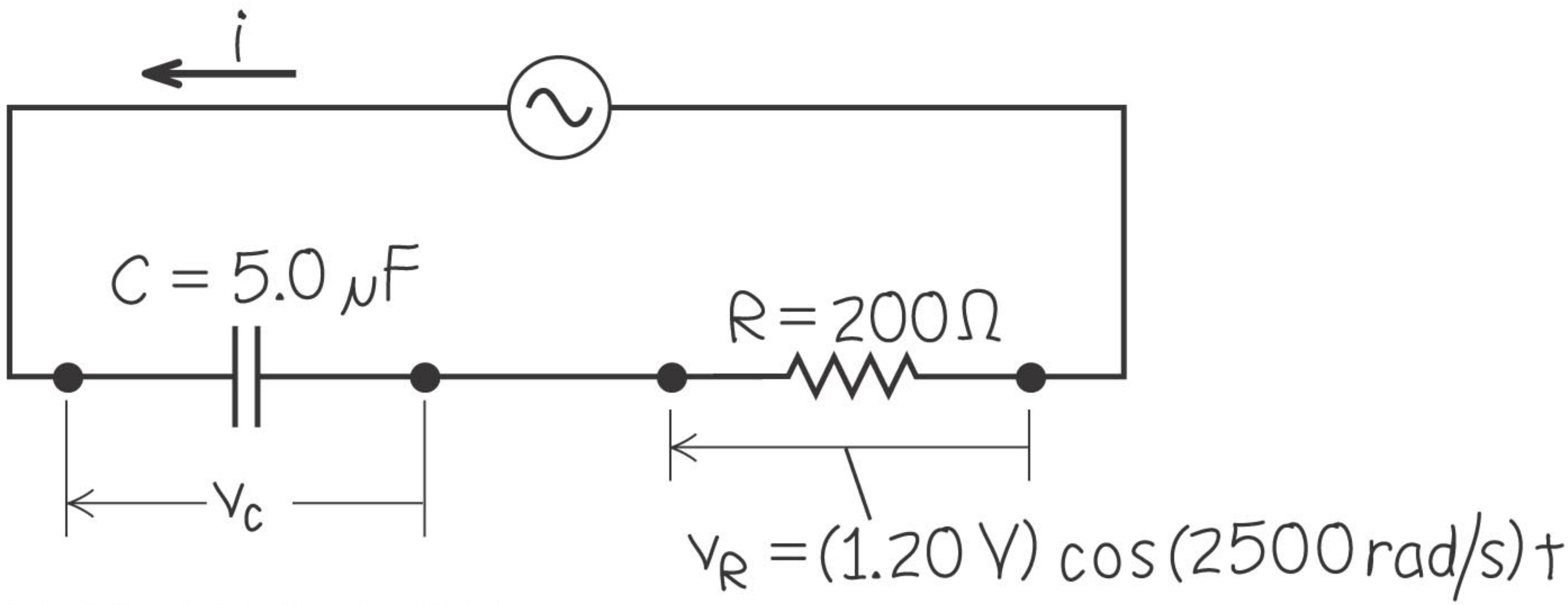
Capacitance in an ac circuit

- Follow the text analysis of a capacitor in an ac circuit using Figure 31.9 below. The voltage amplitude across the capacitor is $V_C = IX_C$.



A resistor and a capacitor in an ac circuit

- Follow Example 31.3, which combines a resistor and a capacitor in an ac circuit. Refer to Figure 31.10 below.



Comparing ac circuit elements

- Table 31.1 summarizes the characteristics of a resistor, an inductor, and a capacitor in an ac circuit.
- Figure 31.11 (below) shows graphs of resistance and reactance.

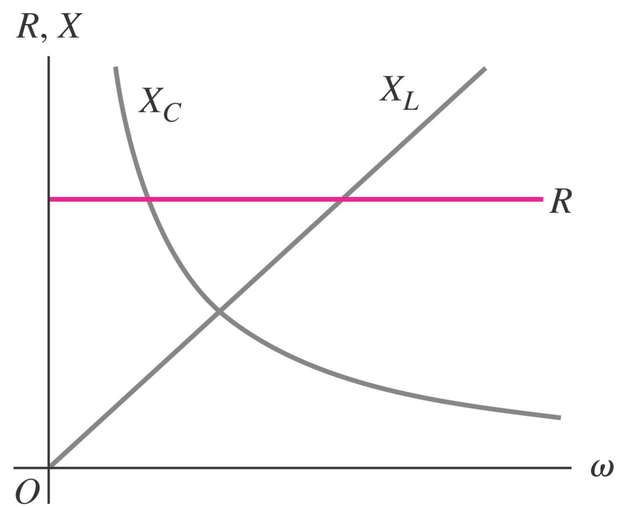


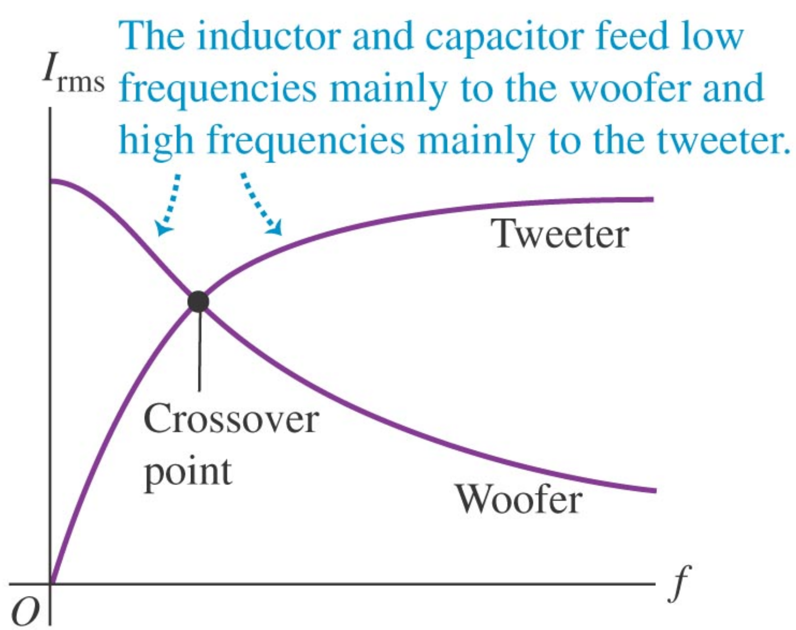
Table 31.1 Circuit Elements with Alternating Current

Circuit Element	Amplitude Relationship	Circuit Quantity	Phase of v
Resistor	$V_R = IR$	R	In phase with i
Inductor	$V_L = IX_L$	$X_L = \omega L$	Leads i by 90°
Capacitor	$V_C = IX_C$	$X_C = 1/\omega C$	Lags i by 90°

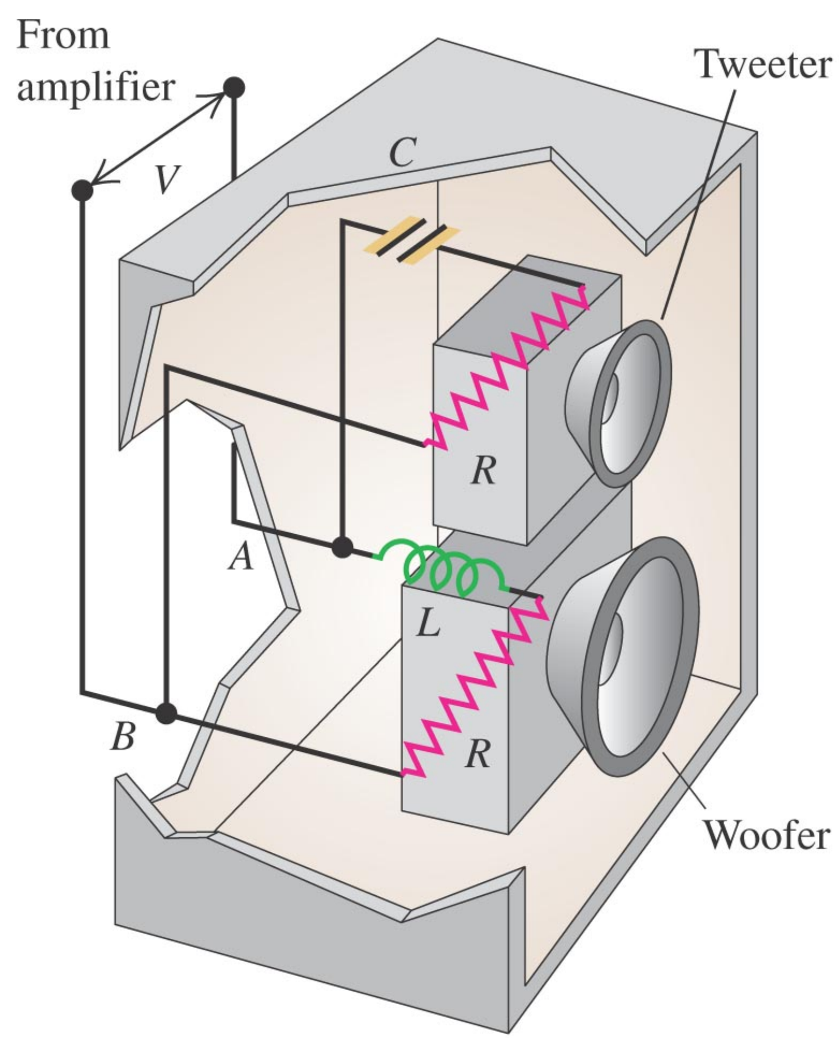
A useful application: the loudspeaker

- The woofer (low tones) and the tweeter (high tones) are connected in parallel across the amplifier output. (See Figure 31.12 shown here.)

Graphs of rms current as functions of frequency for a given amplifier voltage

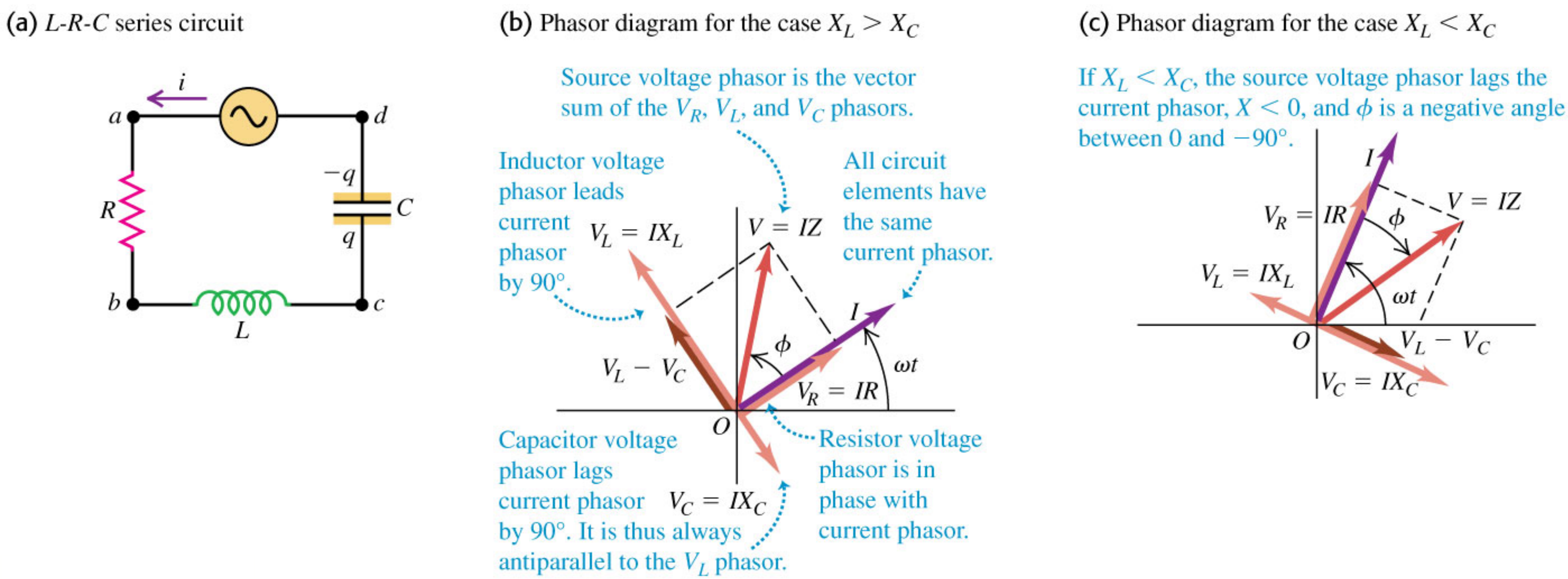


A crossover network in a loudspeaker system



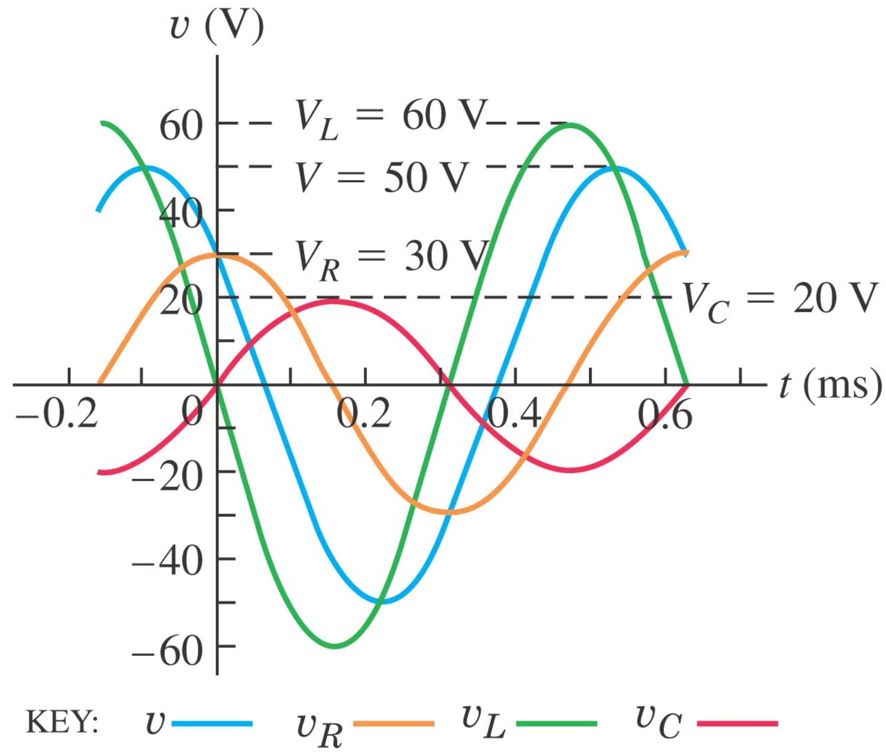
The *L-R-C* series circuit

- Follow the text analysis of the *L-R-C* series circuit, including impedance and phase angle, using Figure 31.13 below.
- The voltage amplitude across an ac circuit is $V = IZ$.



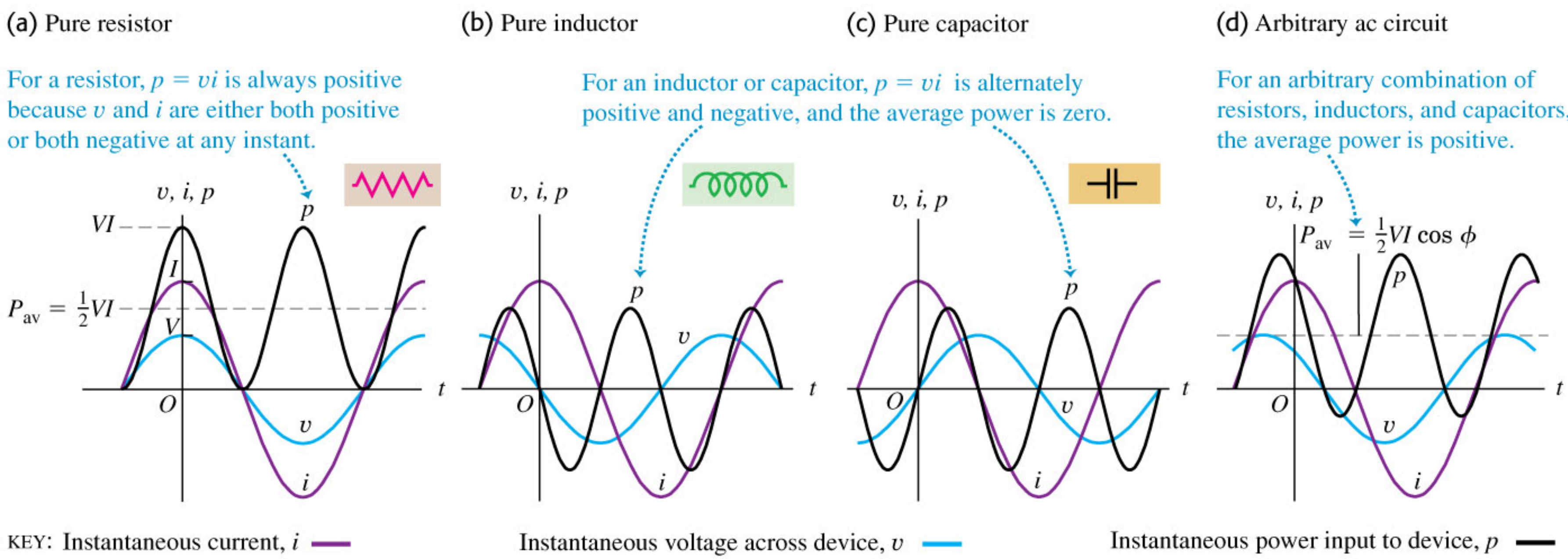
An *L-R-C* series circuit

- Read Problem-Solving Strategy 31.1.
- Follow Example 31.4.
- Follow Example 31.5 using Figure 31.15 at the right.



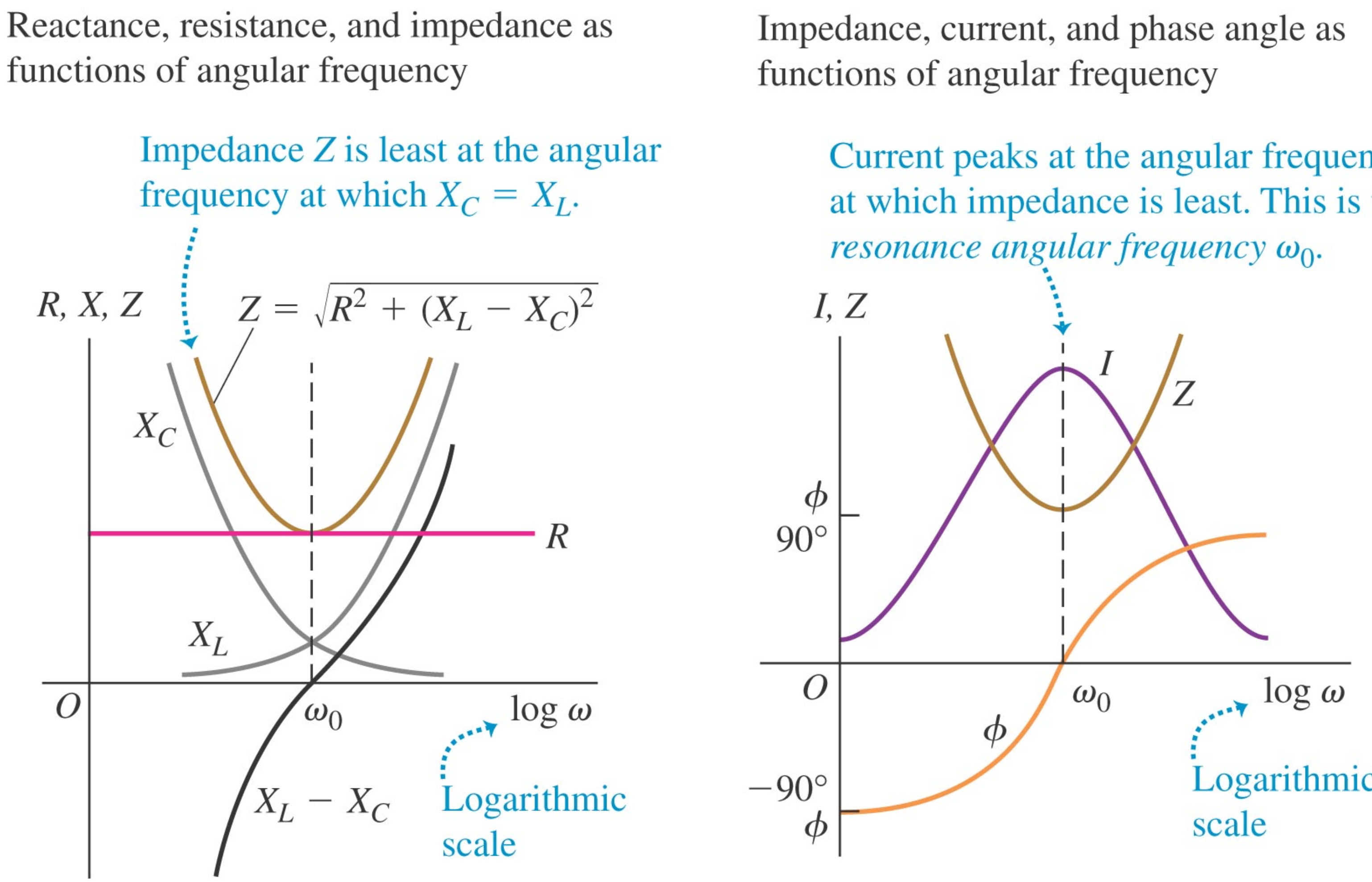
Power in ac circuits

- Follow the text discussion of power in alternating-current circuits using Figure 31.16 below.
- Note that the net energy transfer over one cycle is zero for an inductor and a capacitor.
- Follow Example 31.6 and Example 31.7.



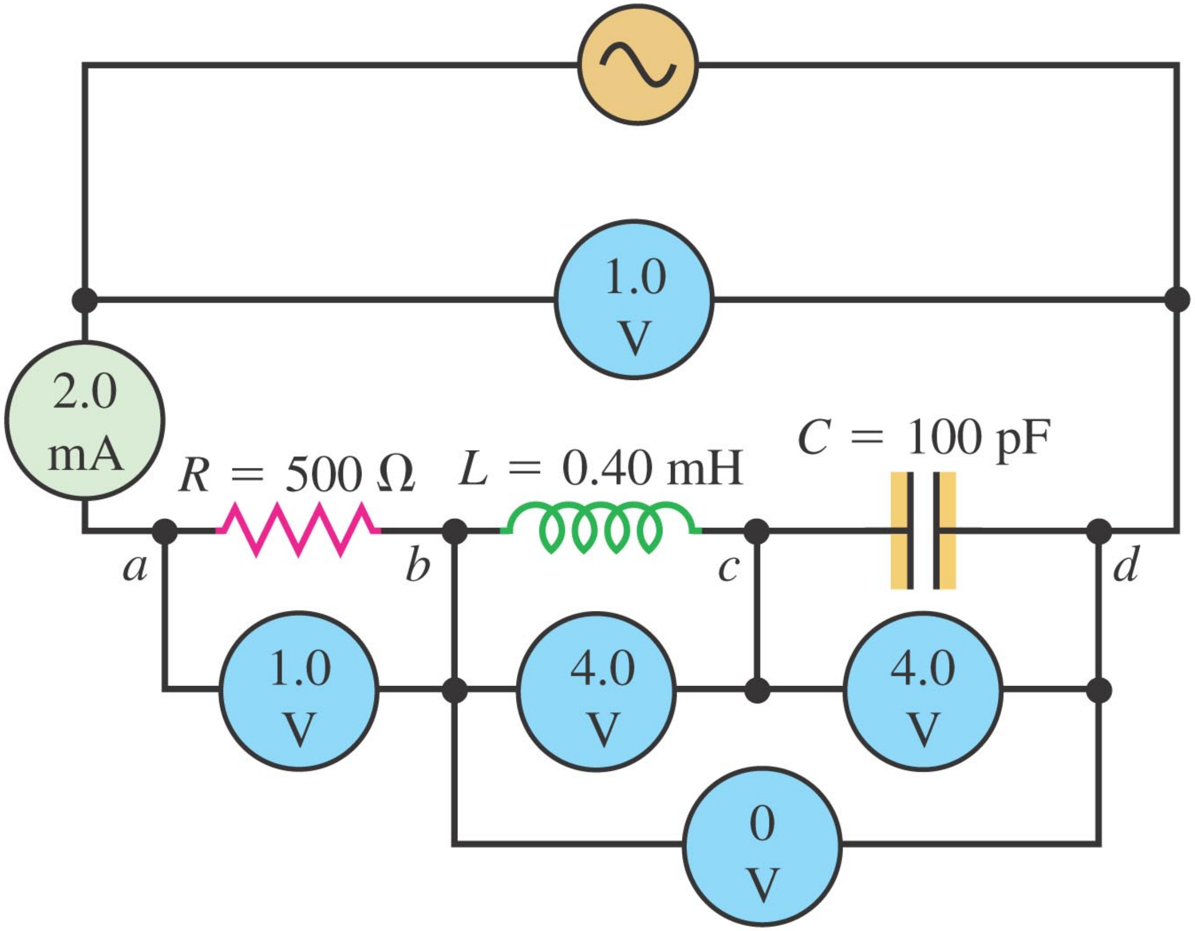
Resonance in ac circuits

- At the *resonance angular frequency* ω_0, the inductive reactance equals the capacitive reactance and the current amplitude is greatest. (See Figure 31.18 below.)



Tuning a radio

- Follow Example 31.8 using Figure 31.20 below.

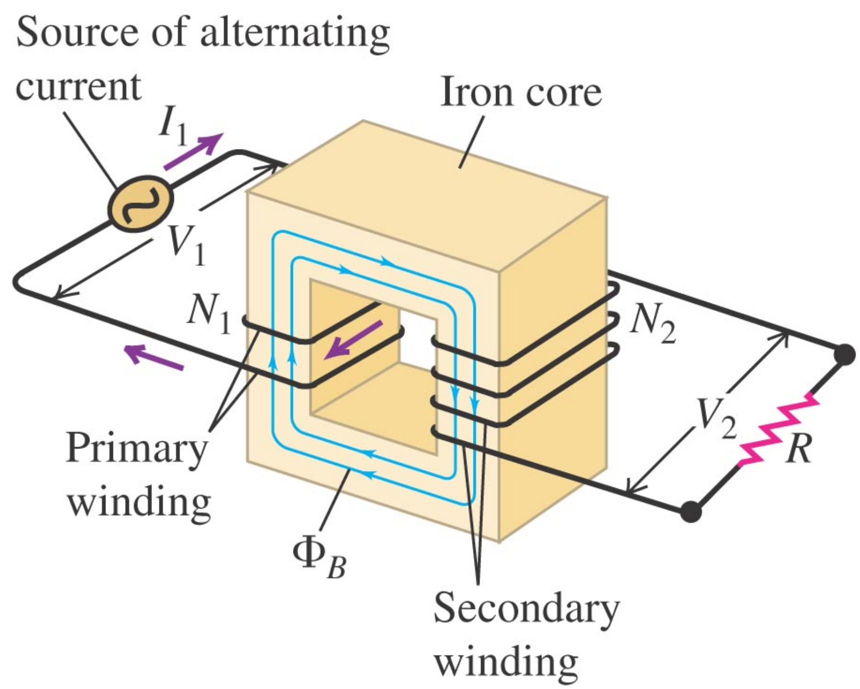


Transformers

- Power is supplied to the *primary* and delivered from the *secondary*. See Figure 31.21 at the right.
- Terminal voltages: $V_2/V_1 = N_2/N_1$.
- Currents in primary and secondary: $V_1 I_1 = V_2 I_2$.

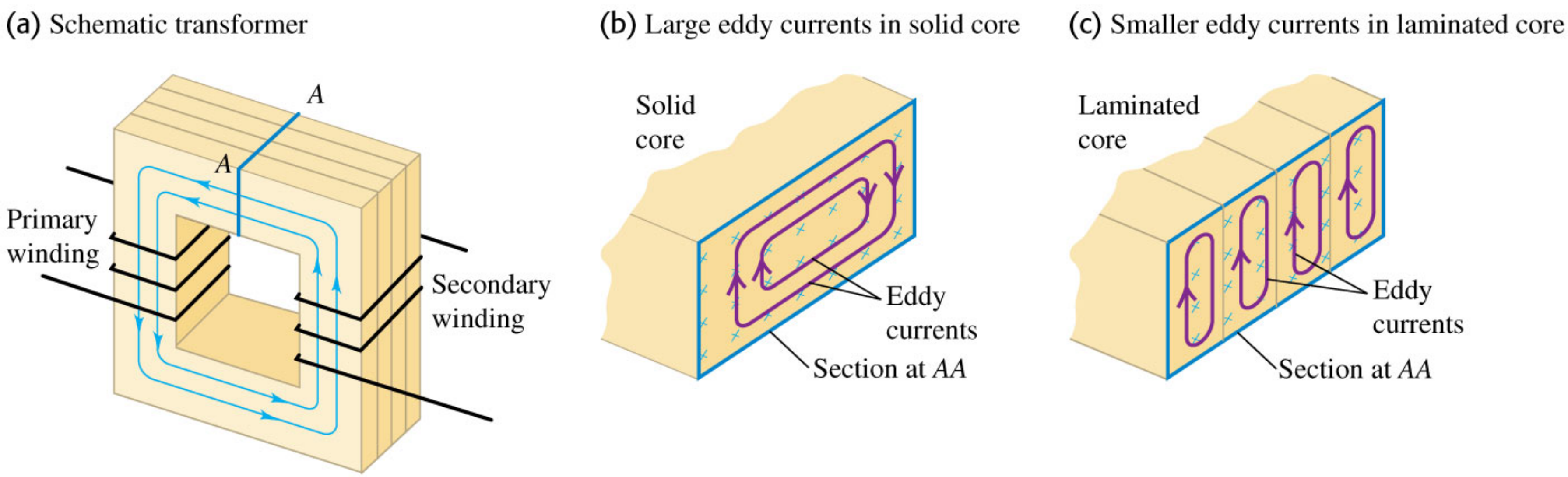
The induced emf *per turn* is the same in both coils, so we adjust the ratio of terminal voltages by adjusting the ratio of turns:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$



Real transformers

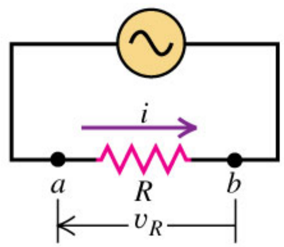
- Real transformers always have some power losses, as illustrated in Figure 31.24 below.
- Follow Example 31.9.



Q31.1

A resistor is connected across an ac source as shown. For this circuit, what is the relationship between the instantaneous current *i* through the resistor and the instantaneous voltage v_{ab} across the resistor?

(a) Circuit with ac source and resistor



A. *i* is maximum at the same time as v_{ab}.

B. *i* is maximum one-quarter cycle before v_{ab}.

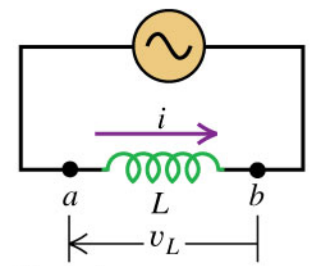
C. *i* is maximum one-quarter cycle after v_{ab}.

D. not enough information given to decide

Q31.2

An inductor is connected across an ac source as shown. For this circuit, what is the relationship between the instantaneous current *i* through the inductor and the instantaneous voltage v_{ab} across the inductor?

(a) Circuit with ac source and inductor



A. *i* is maximum at the same time as v_{ab}.

B. *i* is maximum one-quarter cycle before v_{ab}.

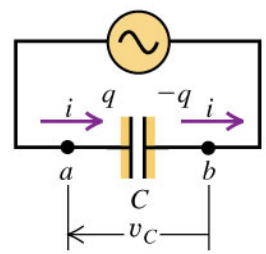
C. *i* is maximum one-quarter cycle after v_{ab}.

D. not enough information given to decide

Q31.3

A capacitor is connected across an ac source as shown. For this circuit, what is the relationship between the instantaneous current *i* through the capacitor and the instantaneous voltage v_{ab} across the capacitor?

(a) Circuit with ac source and capacitor



A. *i* is maximum at the same time as v_{ab}.

B. *i* is maximum one-quarter cycle before v_{ab}.

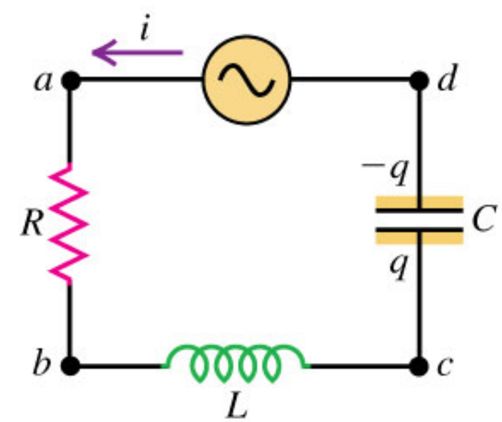
C. *i* is maximum one-quarter cycle after v_{ab}.

D. not enough information given to decide

Q31.4

An *L-R-C* series circuit as shown is operating at its resonant frequency. At this frequency, how are the values of the capacitive reactance X_C, the inductive reactance X_L, and the resistance R related to each other?

(a) *L-R-C* series circuit



A. $X_L = R$; X_C can have any value.

B. $X_C = R$; X_L can have any value.

C. $X_C = X_L$; R can have any value.

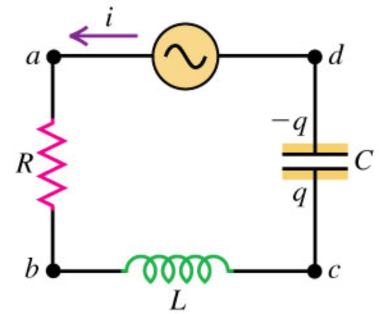
D. $X_C = X_L = R$

E. none of the above

Q31.5

In an *L-R-C* series circuit as shown, the current has a very small amplitude if the ac source oscillates at a very high frequency. Which circuit element causes this behavior?

(a) *L-R-C* series circuit



© 2012 Pearson Education, Inc.

A. the resistor *R*

B. the inductor *L*

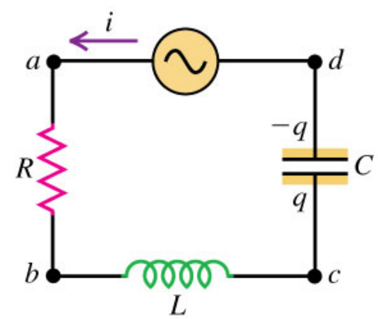
C. the capacitor *C*

D. Misleading question—the current actually has a very *large* amplitude if the frequency is very high.

Q31.6

In an *L-R-C* series circuit as shown, there is a phase angle between the instantaneous current through the circuit and the instantaneous voltage v_{ad} across the entire circuit. For what value of the phase angle is the *greatest power* delivered to the resistor?

(a) *L-R-C* series circuit



A. zero

B. 90°

C. 180°

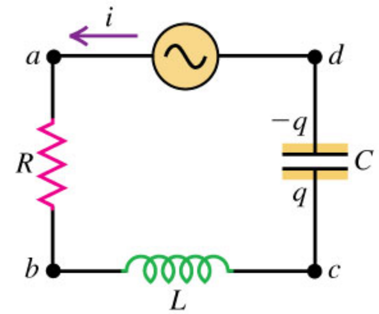
D. 270°

E. none of the above

Q31.7

In an *L-R-C* series circuit as shown, suppose that the angular frequency of the ac source equals the resonance angular frequency. In this case, the circuit impedance

(a) *L-R-C* series circuit



A. is maximum.

B. is minimum, but not zero.

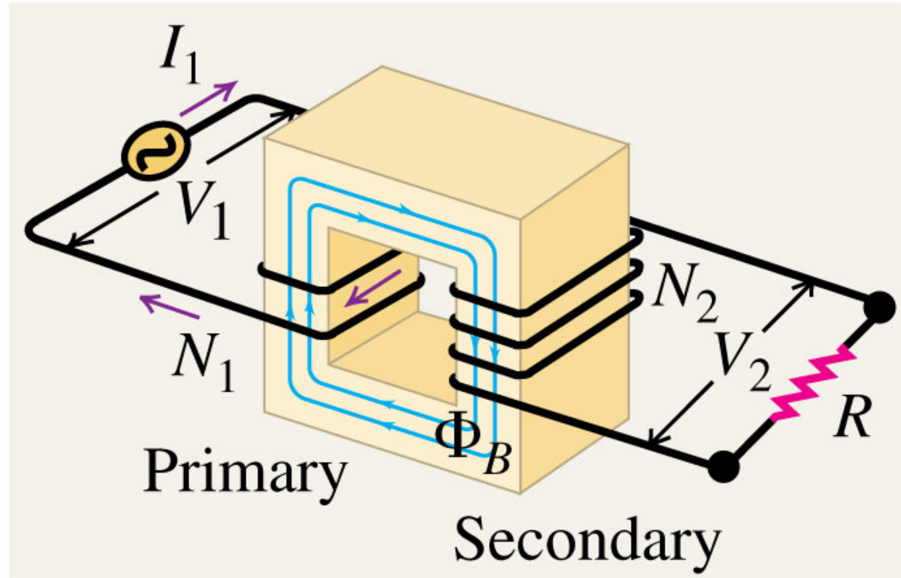
C. is zero.

D. is neither a maximum nor a minimum.

E. not enough information give to decide

Q31.8

In the transformer shown in the drawing, there are more turns in the secondary than in the primary. In this situation, the *voltage amplitude* is



A. greater in the primary than in the secondary.

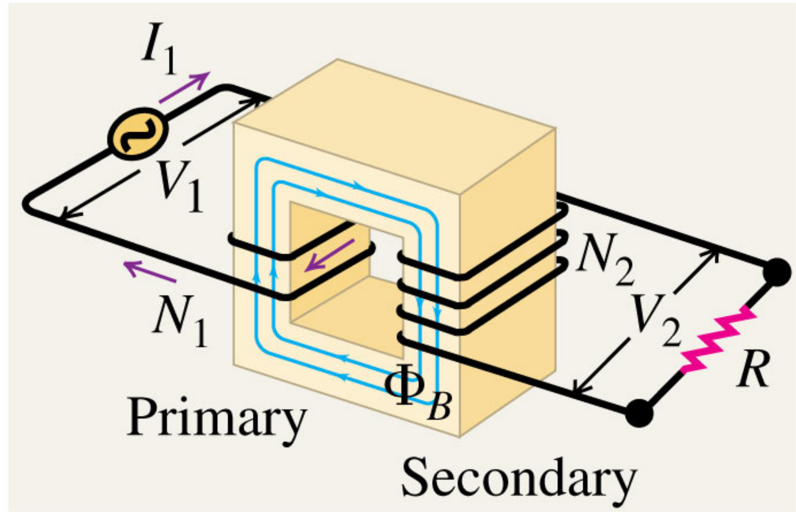
B. smaller in the primary than in the secondary.

C. the same in the primary and in the secondary.

D. not enough information given to decide

Q31.9

In the transformer shown in the drawing, there are more turns in the secondary than in the primary. In this situation, the *current amplitude* is



A. greater in the primary than in the secondary.

B. smaller in the primary than in the secondary.

C. the same in the primary and in the secondary.

D. not enough information given to decide