# Chapter 24: Alternating-Current Circuits

## Outline



## Summary

The generator introduced in Chapter 23 produces alternating, sinusoidal current and voltage. Chapter 24 examines circuits with such an AC generator and a combination of resistors, capacitors and inductors. A generalized notion of resistance, the impedance, is used in analyzing these *RLC* circuits. The phase relationships among the voltage drops across the three different elements and the current are also discussed in detail. Finally, resonance in an *RLC* circuit and its applications are introduced.

## Major Concepts

By the end of the chapter, students should understand each of the following and be able to demonstrate their understanding in problem applications as well as in conceptual situations.

- Alternating current and voltage
  - Phasors and phasor diagrams
  - RMS values
- Motional EMF
- Capacitors in AC circuits
  - Capacitive reactance
  - Phase relation between current and voltage
- Inductors in AC circuits
  - Inductive reactance
  - Phase relation between current and voltage
- *RLC* circuits
  - Impedance
  - Phase angle
  - Power factor
  - Resonance

**Assignment:**

Look at all of the questions.
Make sure you can do the following problems from Ch. 24:
1, 3, 11, 19, 21, 29, & 55
Please Note: Not all of the material is in the text.

Chapter 24: Alternating current

# Summary of main points of chapter

## Sinusoidal currents and voltages; Resistors in ac circuits

An ac generator produces an emf that varies sinusoidally; the maximum value is called the amplitude or peak value. If the only circuit element is a resistor, the current in the resistor also varies sinusoidally. As with simple harmonic motion, the period is the time for the emf to go through one complete cycle; the frequency is the number of complete cycles per second; and the angular frequency is the frequency multiplied by $2\pi$.

**Power dissipated in a resistor:** The instantaneous power dissipated by a resistor is the instantaneous current multiplied by the instantaneous voltage; in a purely resistive circuit, it varies like the sine squared, and is therefore always non-negative. The average power, which is usually of more interest, is half the peak power; the rms value (the "average") of the current or voltage is the peak value divided by the square root of two.

## Electricity in the home

Most home electrical outlets in North America supply an rms voltage of 110 to 120 volts at a frequency of 60 Hz. Some large appliances, however, run on 220 to 240 volts, especially electric ranges and clothes dryers. As with transmission lines, the higher voltage means lower current for the same power, and less resistive loss. The transmission lines are at high voltage; transformers on poles reduce the voltage just before delivering electricity to homes and businesses. There is a central tap on the secondary transformer, which is grounded; the voltage between this and either hot line is 120 volts. The voltage between the two hot lines is 240 volts (they are 180º out of phase with each other). A two-prong outlet has a hot side and a neutral side (polarized outlets and plugs can only be inserted one way); a three-prong outlet also has a direct connection to ground.

## Capacitors in ac circuits

If an ac circuit consists only of a capacitor, the voltage across the capacitor is equal to the voltage of the source. The charge on the capacitor is proportional to the voltage, so the current is proportional to the rate of change of the voltage. This means that the current is 90º out of phase with the voltage; we say that the current leads the voltage (it is ahead).

The amplitude of the current is proportional to the amplitude of the voltage; the proportionality constant is called the reactance of the capacitor. The reactance is inversely proportional to the capacitance and also to the angular frequency; it has dimensions of resistance.

The power dissipated in a capacitor is proportional to the instantaneous voltage multiplied by the instantaneous current; due to the phase difference in the current and voltage, the average power dissipated by a capacitor is zero.

## Inductors in ac circuits

The voltage in an inductor is proportional to the rate of change of the current; the proportionality constant is again called the reactance, and is the product of the angular frequency and the inductance. The current and voltage are again 90º out of phase, but this time the current lags the voltage.

**Power:** Once again, the instantaneous power is the instantaneous current multiplied by the instantaneous voltage, and, due to the phase relationship, the average power dissipated in the inductor is zero.

## RLC series circuits

In a series RLC circuit, the instantaneous currents through each circuit element are the same, but the instantaneous voltages are out of phase with each other. It can be shown that the amplitude of the source voltage is proportional to the amplitude of the current; the proportionality constant is called the impedance, and depends on the resistance and on the inductive and capacitive reactances.

**Power factor:** No power is dissipated in either the capacitor or the inductor; the power dissipated in the resistor depends on the impedance. The power factor is the resistance divided by the impedance; the power is the rms current multiplied by the rms voltage multiplied by the power factor.

## Resonance in an RLC circuit

The impedance of a series RLC circuit depends on the frequency, and is a minimum (equal to the resistance) when the capacitive and inductive reactances are equal. If the impedance is a minimum, the current and power are maximum; the frequency at which this occurs is called the resonant frequency, and depends only on the inductance and the capacitance.