Chapter 23

Alternating Current Circuits

23.1 Capacitors and Capacitive Reactance

The resistance in a purely resistive circuit has the same value at all frequencies.

\[ V_{\text{rms}} = I_{\text{rms}} R \]

Example 1 A Capacitor in an AC Circuit

The capacitance is 1.50µF and the rms voltage is 25.0 V. What is the rms current when the frequency is (a) 100 Hz and (b) 5000 Hz?
23.1 Capacitors and Capacitive Reactance

(a)
\[ X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(100 \text{ Hz})(1.50 \times 10^{-4} \text{ F})} = 1060\Omega \]
\[ I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{25.0 \text{ V}}{1060\Omega} = 0.0236 \text{ A} \]

(b)
\[ X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(5000 \text{ Hz})(1.50 \times 10^{-4} \text{ F})} = 21.2\Omega \]
\[ I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{25.0 \text{ V}}{21.2\Omega} = 1.18 \text{ A} \]

For a purely resistive circuit, the current and voltage are in phase.

In the phasor model, the voltage and current are represented by rotating arrows (called phasors).

These phasors rotate at a frequency \( f \).

The vertical component of the phasor is the instantaneous value of the current or voltage.

The current in a capacitor leads the voltage across the capacitor by a phase angle of 90 degrees.

The average power used by a capacitor in an ac circuit is zero.
23.2 Inductors and Inductive Reactance

Inductive reactance

\[ V_{\text{rms}} = I_{\text{rms}} X_L \]

\[ X_L = 2\pi f L \]

The current lags behind the voltage by a phase angle of 90 degrees.

The average power used by an inductor in an ac circuit is zero.

23.3 Circuits Containing Resistance, Capacitance, and Inductance

In a series RLC circuit, the total opposition to the flow is called the **impedance**.

\[ V_{\text{rms}} = I_{\text{rms}} Z \quad Z = \sqrt{R^2 + (X_L - X_C)^2} \]
### 23.3 Circuits Containing Resistance, Capacitance, and Inductance

#### Circuit Impedance

The impedance of a circuit containing resistance, capacitance, and inductance is given by:

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

where
- \( R \) is the resistance,
- \( X_L \) is the inductive reactance,
- \( X_C \) is the capacitive reactance.

**Phase Angle**

The phase angle \( \phi \) between the current and total voltage is:

\[ \tan \phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} \]

**Power**

The power dissipated in the circuit is:

\[ P = I_{\text{rms}}^2 Z \cos \phi = I_{\text{rms}} V_{\text{rms}} \cos \phi \]

### 23.4 Resonance in Electric Circuits

**Resonance** occurs when the frequency of a vibrating force exactly matches a natural (resonant) frequency of the object to which the force is applied. The oscillation of a mass on a spring is analogous to the oscillation of the electric and magnetic fields that occur, respectively, in a capacitor and an inductor.

**Resonant Frequency**

The resonant frequency \( f_0 \) is given by:

\[ f_0 = \frac{1}{2\pi \sqrt{LC}} \]

where
- \( L \) is the inductance,
- \( C \) is the capacitance.
Semiconductor devices such as diodes and transistors are widely used in modern electronics.

The semiconducting materials (silicon and germanium) used to make diodes and transistors are doped by adding small amounts of an impurity element.

At the junction between the n and p materials, mobile electrons and holes combine and create positive and negative charge layers.
There is an appreciable current through the diode when the diode is forward biased. Under a reverse bias, there is almost no current through the diode.

A half-wave rectifier.

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A bipolar junction transistor can be used to amplify a smaller voltage into a larger one.