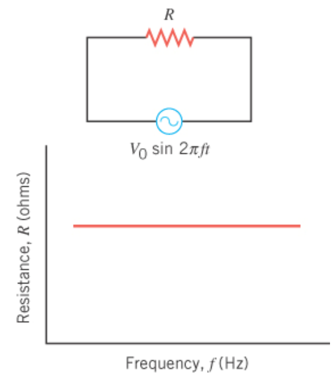
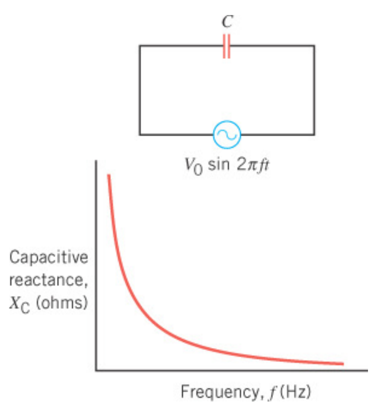
Chapter 23

Alternating Current Circuits

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



$$V_{\text{rms}} = I_{\text{rms}} R$$

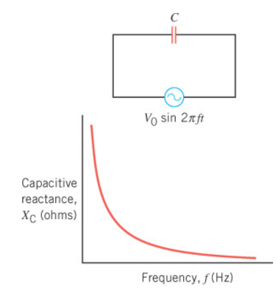


capacitive reactance

$$V_{\text{rms}} = I_{\text{rms}} X_C \qquad X_C = \frac{1}{2\pi fC}$$

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?

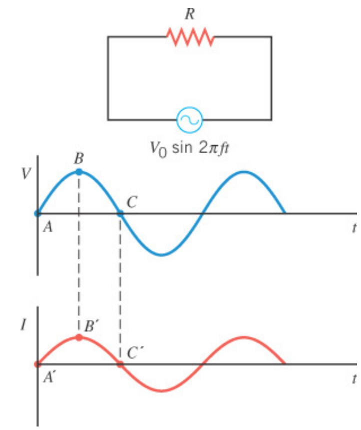


(a) $$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(100\,\text{Hz})(1.50\times10^{-6}\,\text{F})} = 1060\Omega$$

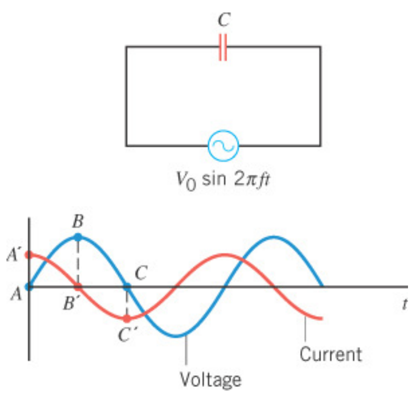
$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{25.0\,\text{V}}{1060\Omega} = 0.0236\,\text{A}$$

(b) $$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(5000\,\text{Hz})(1.50\times10^{-6}\,\text{F})} = 21.2\Omega$$

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{25.0\,\text{V}}{21.2\Omega} = 1.18\,\text{A}$$

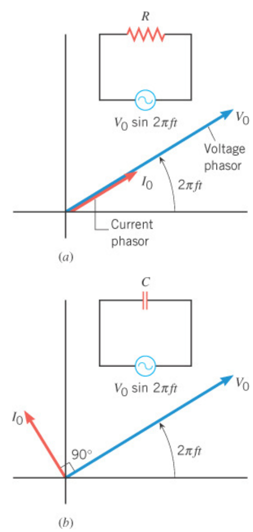


For a purely resistive circuit, the current and voltage are ***in phase***.



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.



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

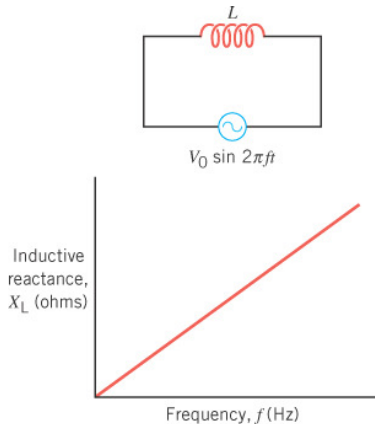
These phasors rotate at a frequency *f*.

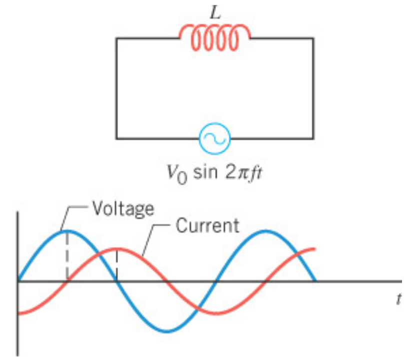
The vertical component of the phasor is the instantaneous value of the current or voltage.

inductive reactance

$$V_{\text{rms}} = I_{\text{rms}} X_L$$

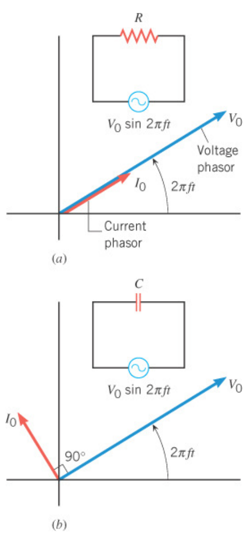
$$X_L = 2\pi f L$$

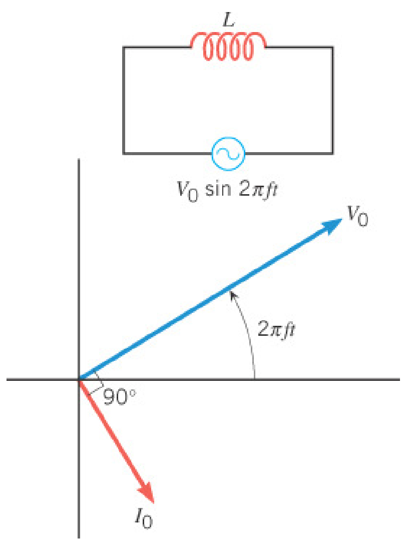


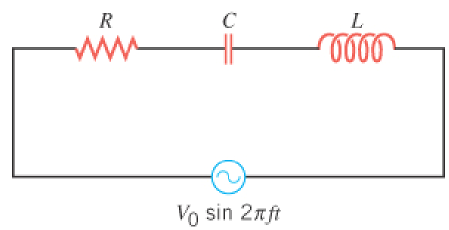


The current ***lags*** behind the voltage by a phase angle of 90 degrees.

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



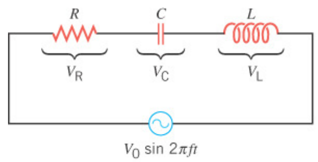




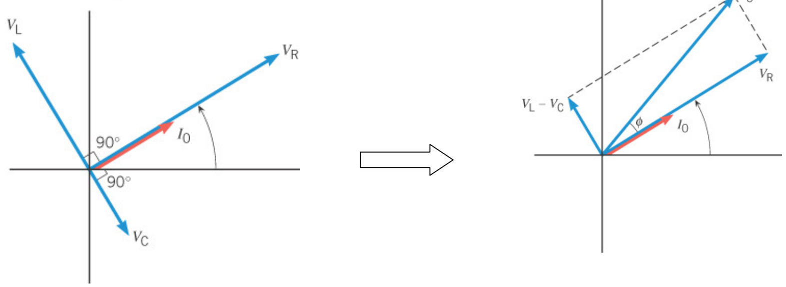
In a series RLC circuit, the total opposition to the flow is called the ***impedance***.

$$V_{\text{rms}} = I_{\text{rms}} Z \qquad Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$$

23.3 Circuits Containing Resistance, Capacitance, and Inductance



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



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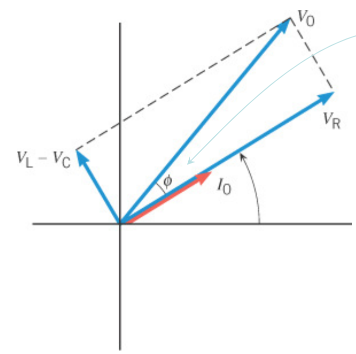


phase angle between
current and total voltage

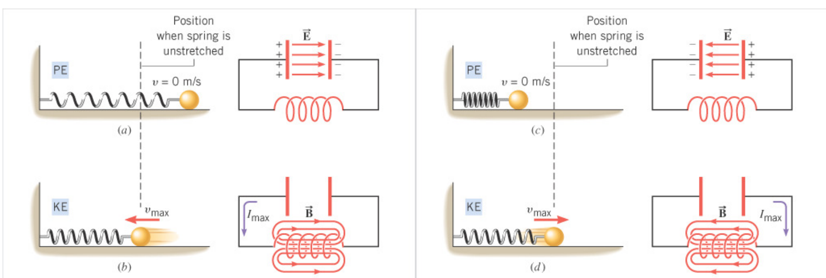
$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

$$\overline{P} = I_{\text{rms}}^2 Z\cos\phi = I_{\text{rms}} V_{\text{rms}} \cos\phi$$

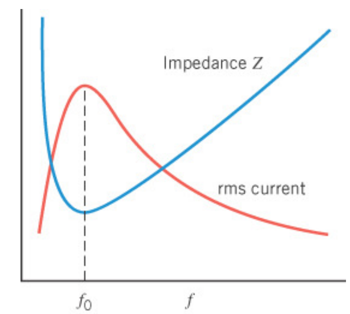
23.4 Resonance in Electric Circuits

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.



23.4 Resonance in Electric Circuits

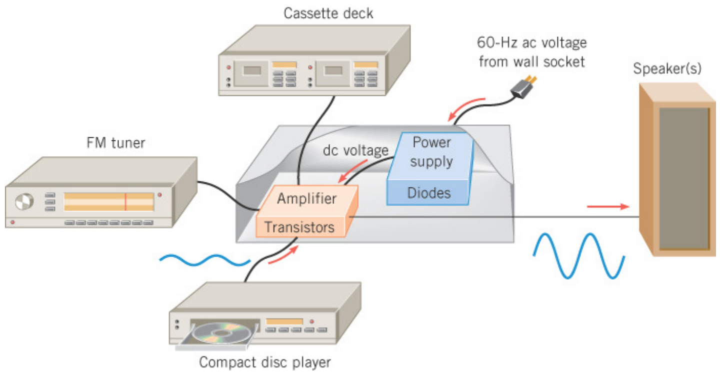


$$I_{\text{rms}} = \frac{V_{\text{rms}}}{\sqrt{R^2 + \left(2\pi fL - 1/2\pi fC\right)^2}}$$

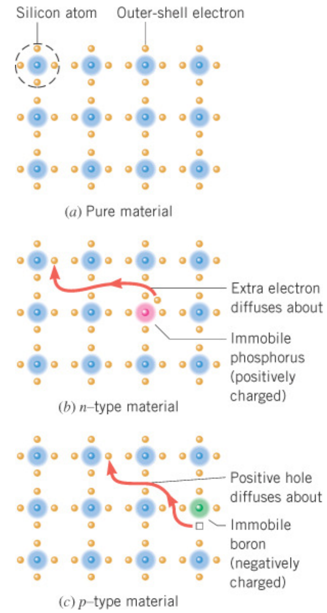
$$Z = \sqrt{R^2 + \left(2\pi fL - 1/2\pi fC\right)^2}$$

Resonant frequency $$f_o = \frac{1}{2\pi\sqrt{LC}}$$

Semiconductor devices such as diodes and transistors are widely used in modern electronics.

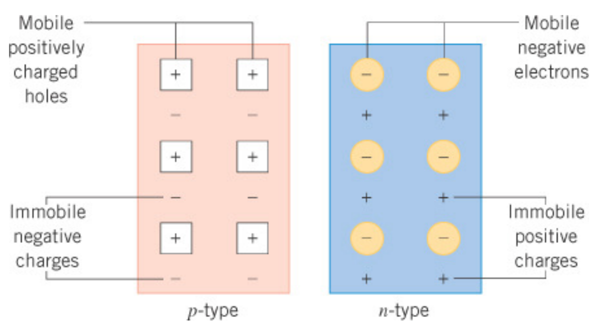


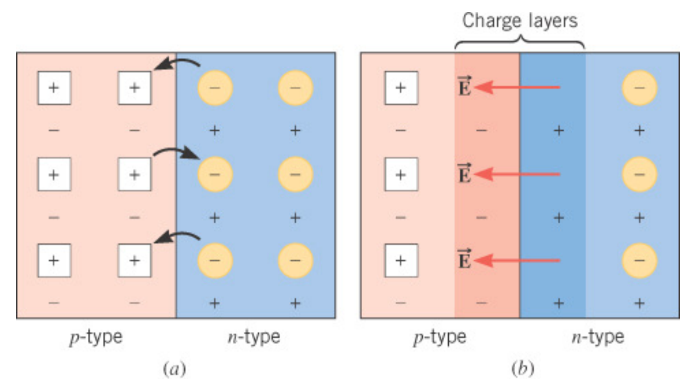
n-TYPE AND p-TYPE SEMICONDUCTORS



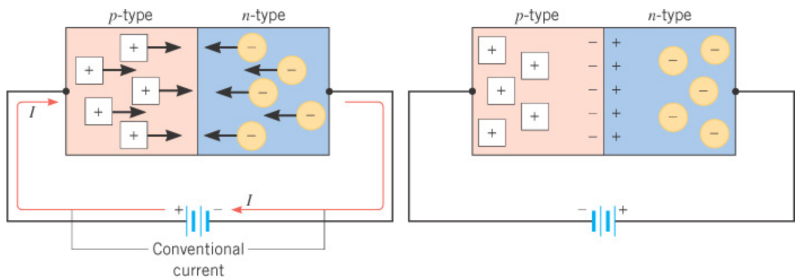
The semiconducting materials (silicon and germanium) used to make diodes and transistors are ***doped*** by adding small amounts of an impurity element.

THE SEMICONDUCTOR DIODE





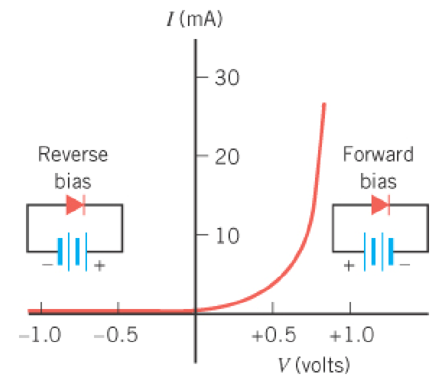
At the junction between the n and p materials, mobile electrons and holes combine and create positive and negative charge layers.



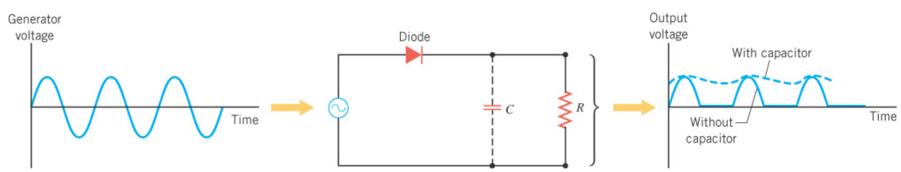
(a) Forward bias (b) Reverse bias

There is an appreciable current through the diode when the diode is forward biased.

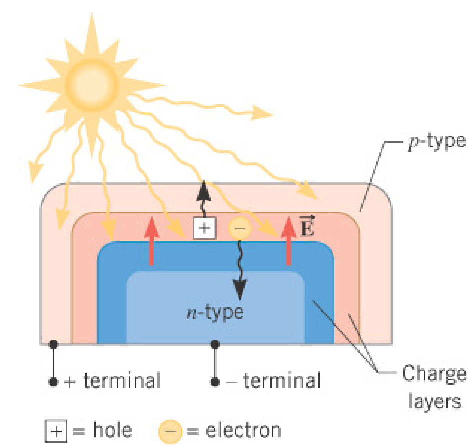
Under a reverse bias, there is almost no current through the diode.



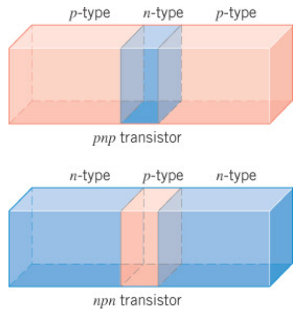
A half-wave rectifier.



SOLAR CELLS



TRANSISTORS



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