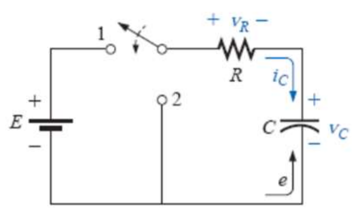
RL and RC Circuits with DC Charging and Discharging

And

AC Circuits

1

TRANSIENTS IN CAPACITIVE NETWORKS: CHARGING PHASE



$$i_C = \frac{E}{R}e^{-t/RC}$$

$$v_C = E(1 - e^{-t/RC})$$

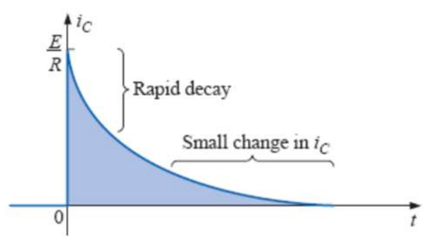
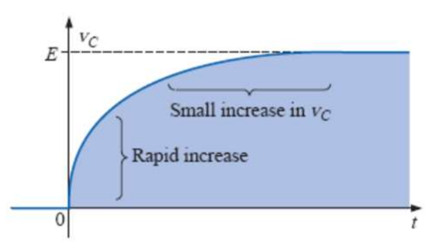


FIG. 10.25
i_C during the charging phase.



The voltage across a capacitor cannot change instantaneously.

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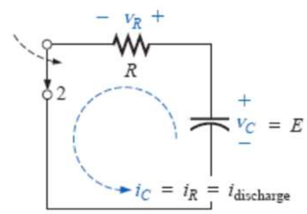
TRANSIENTS IN CAPACITIVE NETWORKS: DISCHARGING PHASE

$$\boxed{i_C = \frac{E}{R}e^{-t/RC}} \quad \textit{discharging}$$

$$\boxed{v_C = Ee^{-t/RC}} \quad \textit{discharging}$$

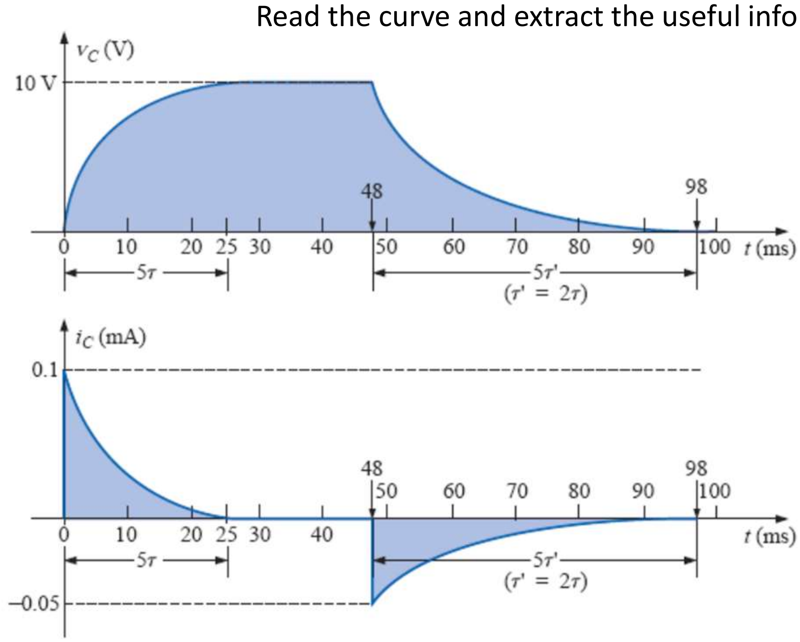


The voltage $v_R = v_C$, and

$$\boxed{v_R = Ee^{-t/RC}} \quad \textit{discharging}$$

3

Read the curve and extract the useful information



Note: The time constant of charging and discharging may or may not be same.

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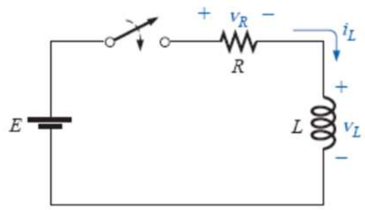
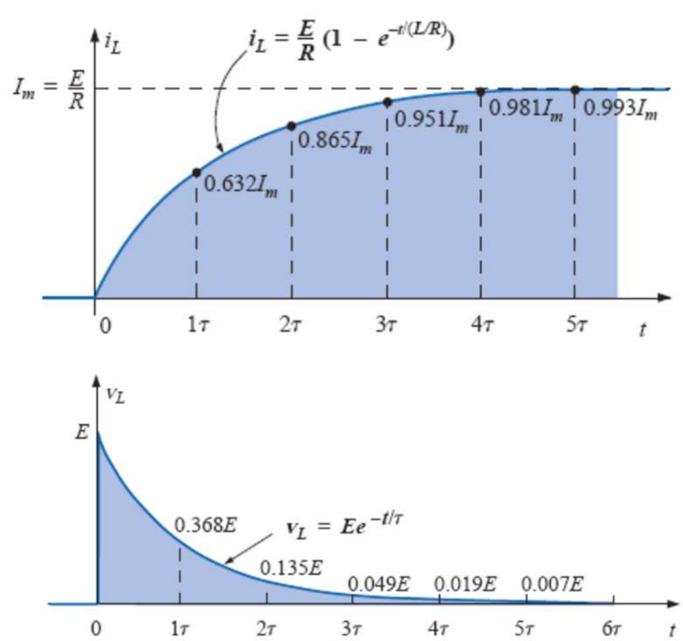


current cannot change instantaneously in an inductive network.



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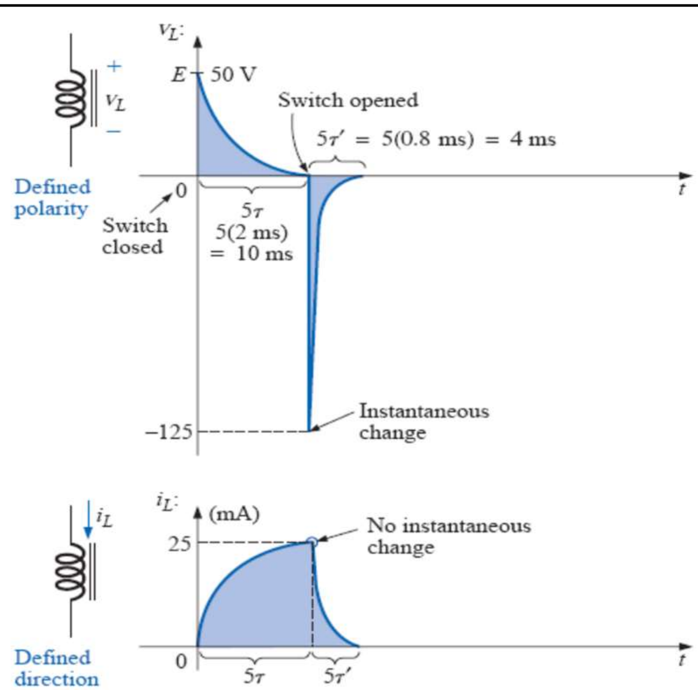

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RC circuits
Time constant τ= RC
Independent sources to zero, calculate Req, Ceq, τeq

Determine initial conditions V(0+) or I(0+)

$V_c(0+) = V_c(0-)$
$I_L(0+) \neq I_L(0-)$

Determine final condition V(∞) or I(∞)

Final response
V(t) = V(∞)+[V(0+) - V(∞)] $e^{-t/\tau}$
Or
I(t) = I(∞)+[I(0+) - I(∞)] $e^{-t/\tau}$

RL circuits
Time constant τ= L/R
Independent sources to zero, calculate Req, Leq, τeq

Determine initial conditions V(0+) or I(0+)

$I_L(0+) = I_L(0-)$
$V_c(0+) \neq V_c(0-)$

Determine final condition V(∞) or I(∞)

Final response
V(t) = V(∞)+[V(0+) - V(∞)] $e^{-t/\tau}$
Or
I(t) = I(∞)+[I(0+) - I(∞)] $e^{-t/\tau}$

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AC Circuits (Steady State)

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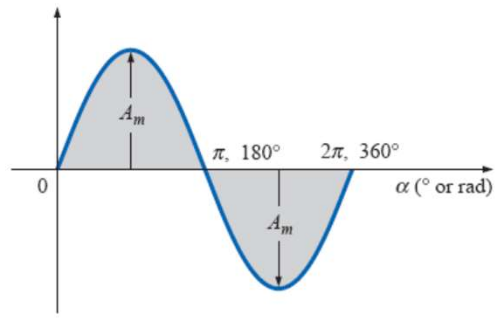
THE SINUSOIDAL VOLTAGE OR CURRENT WAVE FORM

$$i = I_m \sin \omega t = I_m \sin \alpha$$

$$e = E_m \sin \omega t = E_m \sin \alpha$$



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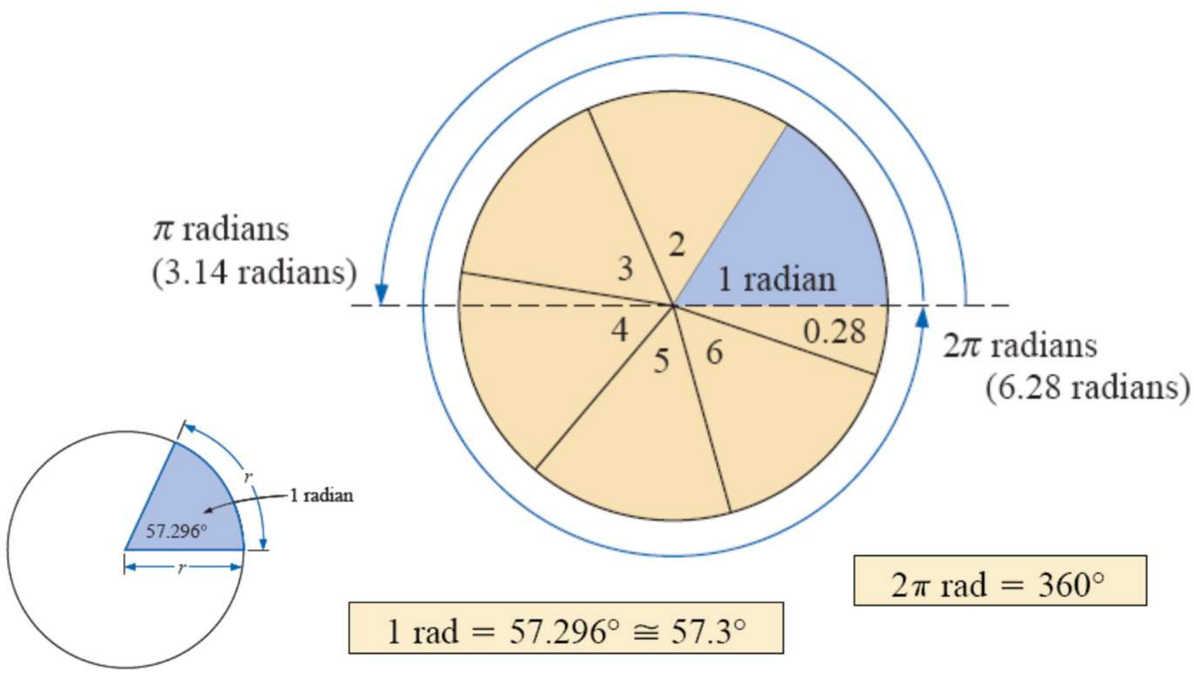

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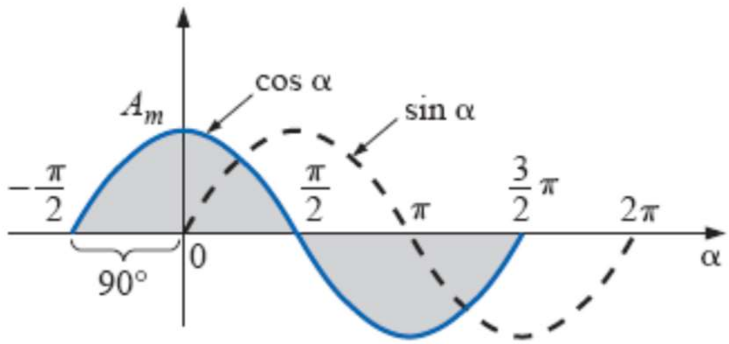
Concept of Lead and Lag



The terms *lead* and *lag* are used to indicate the relationship between two sinusoidal waveforms of the *same frequency* plotted on the same set of axes.

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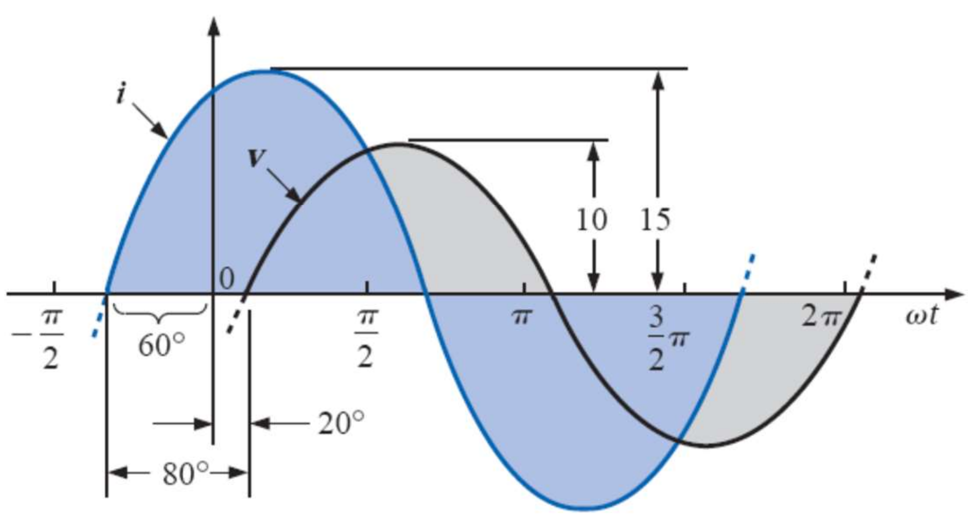
***i* leads *v* by 80°, or *v* lags *i* by 80°.**



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EFFECTIVE (rms) VALUES

$$\boxed{I_{eq(dc)} = I_{eff} = 0.707 I_m}$$

I_m = Peak Value (amplitude)
$I_{eff} = I_{rms} = I_m/\sqrt{2}$

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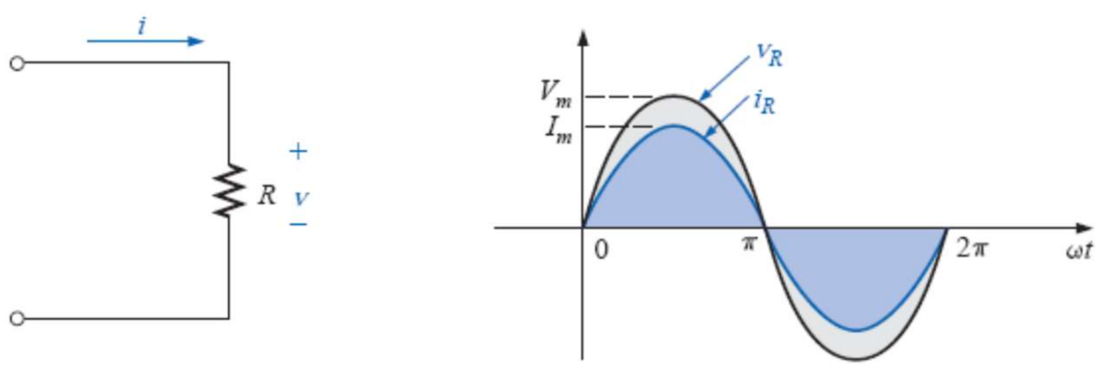
RESPONSE OF *R to* SINUSOIDAL VOLTAGE OR CURRENT



For a purely resistive element, the voltage across and the current through the element are in phase, with their peak values related by Ohm's law.

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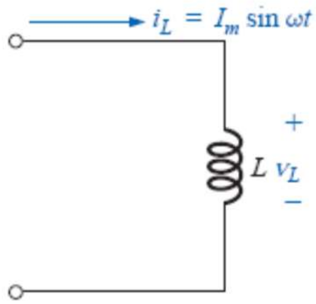
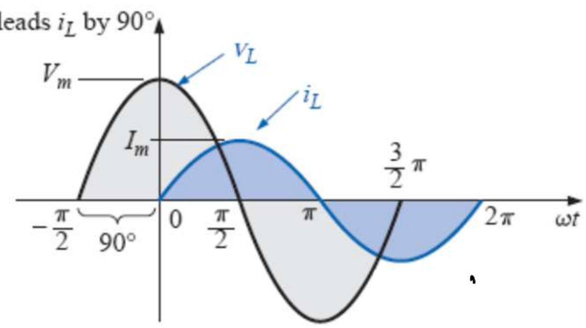
RESPONSE OF “*L*” *to* SINUSOIDAL VOLTAGE OR CURRENT



$$v_L = L \frac{di_L}{dt}$$



$$\boxed{i_L = \frac{1}{L} \int v_L \, dt}$$

For an inductor, v_L leads i_L by 90°, or i_L lags v_L by 90°.

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Reactance Offered by an Inductor

$$\boxed{X_L = \omega L} \qquad \text{(ohms, } \Omega\text{)}$$

$$\boxed{X_L = \frac{V_m}{I_m}} \qquad \text{(ohms, } \Omega\text{)}$$

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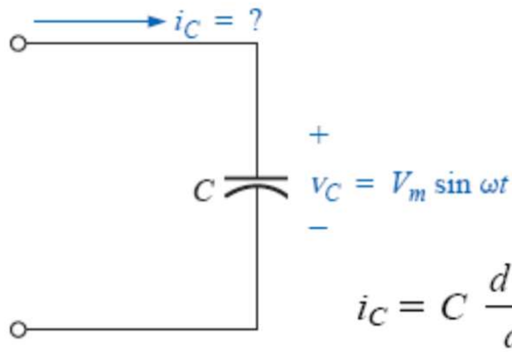
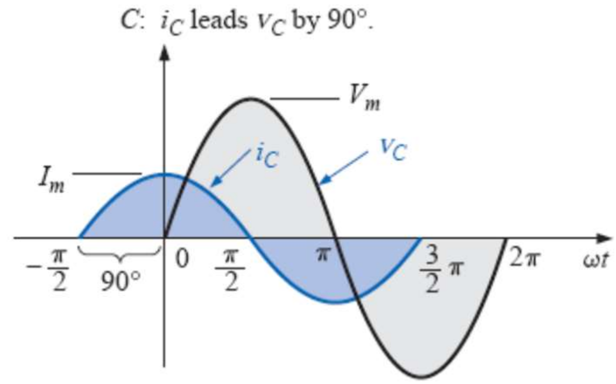
RESPONSE OF "*C*" *to* SINUSOIDAL VOLTAGE OR CURRENT



$$i_C = C \frac{dv_C}{dt}$$



$$\boxed{v_C = \frac{1}{C}\int i_C \, dt}$$

For a capacitor, i_C leads v_C by 90°, or v_C lags i_C by 90°.

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Reactance Offered by a Capacitor

$$\boxed{X_C = \frac{1}{\omega C}} \quad \text{(ohms, } \Omega\text{)}$$

$$\boxed{X_C = \frac{V_m}{I_m}} \quad \text{(ohms, } \Omega\text{)}$$

Like the inductor, the capacitor does *not* dissipate energy in any form (ignoring the effects of the leakage resistance)

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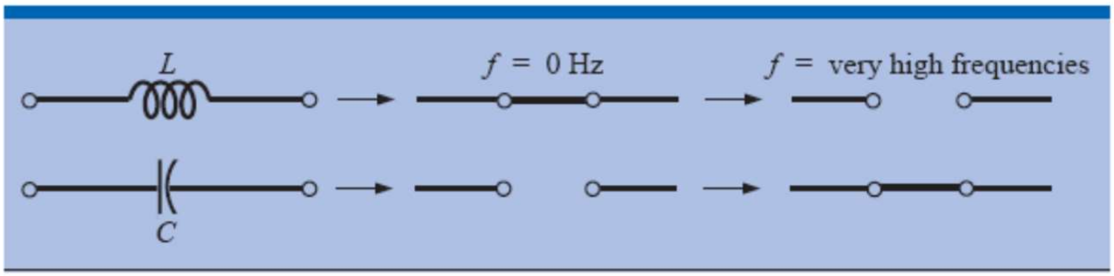
Effect of high and low frequencies on the circuit model of an inductor and a capacitor.



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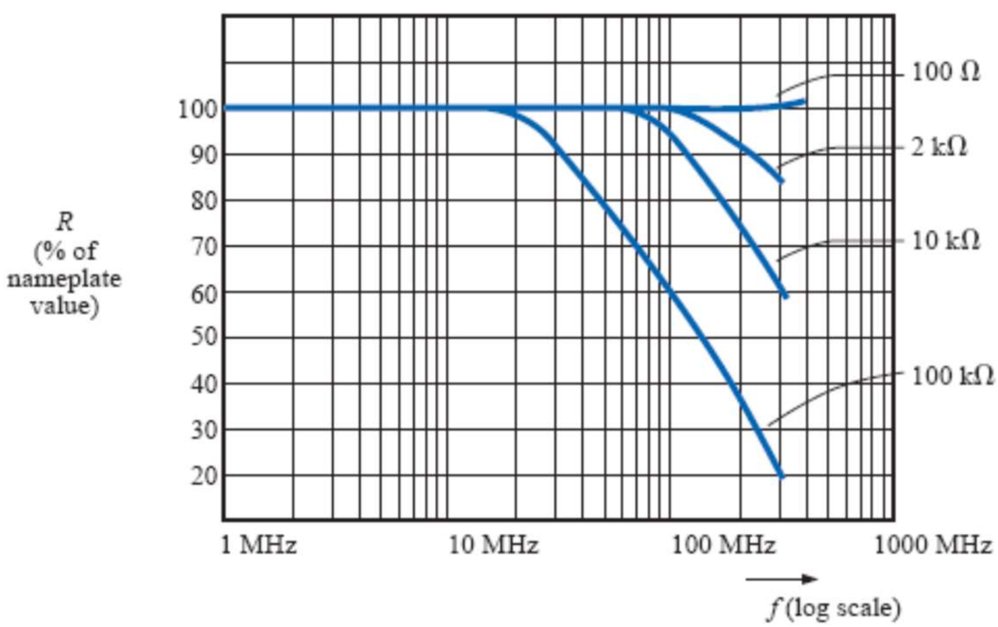
FREQUENCY RESPONSE OF THE BASIC ELEMENTS



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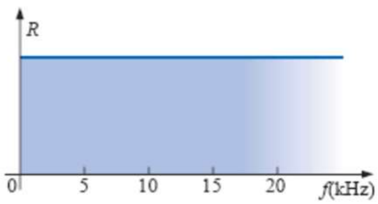
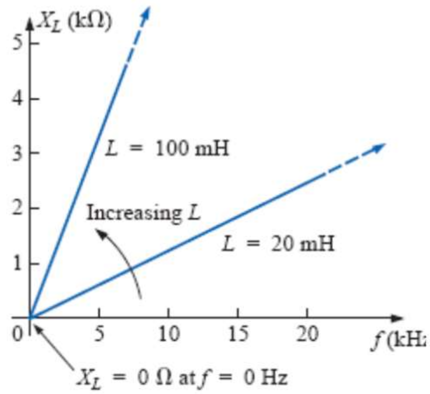
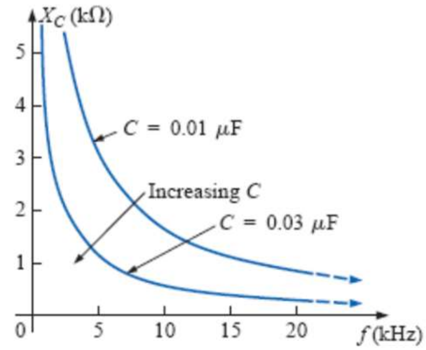


FIG. 14.21
R versus f for the range of interest.



$X_L = \omega L = 2\pi f L = 2\pi L f$



$X_C = \frac{1}{2\pi f C}$

as the applied frequency increases, the resistance of a resistor remains constant, the reactance of an inductor increases linearly, and the reactance of a capacitor decreases nonlinearly.

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Instantaneous Power

$$v = V_m \sin(\omega t + \theta_v)$$
$$i = I_m \sin(\omega t + \theta_i)$$

$$p = vi$$

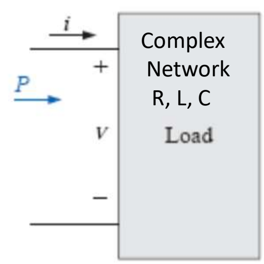

FIG. 14.28
Determining the power delivered in a sinusoidal ac network.

Using the trigonometric identity

$$\sin A \sin B = \frac{\cos(A - B) - \cos(A + B)}{2}$$

so that

$$p = \overbrace{\left[\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)\right]}^{\text{Fixed value}} - \overbrace{\left[\frac{V_m I_m}{2}\cos(2\omega t + \theta_v + \theta_i)\right]}^{\text{Time-varying (function of } t)}$$

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so that

$$p = \underbrace{\left[\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)\right]}_{\text{Fixed value}} - \underbrace{\left[\frac{V_m I_m}{2}\cos(2\omega t + \theta_v + \theta_i)\right]}_{\text{Time-varying (function of } t\text{)}}$$

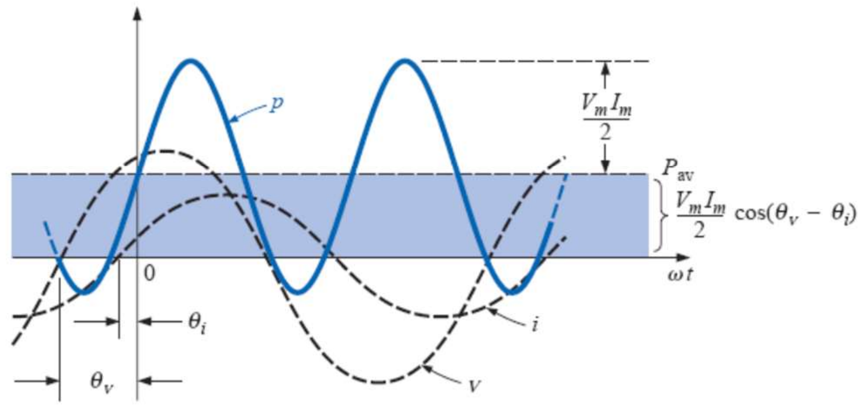

FIG. 14.29
Defining the average power for a sinusoidal ac network.

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Average power

The average power, or **real power** is sometimes called, the power delivered to and dissipated by the load.

the magnitude of average power delivered is independent of whether v leads i or i leads v.

$$\boxed{P = \frac{V_m I_m}{2}\cos\theta} \quad \text{(watts, W)} \qquad \theta = |\theta_v - \theta_i|$$

$$\boxed{P = V_{eff} I_{eff} \cos\theta} \qquad V_{eff} = \frac{V_m}{\sqrt{2}} \quad \text{and} \quad I_{eff} = \frac{I_m}{\sqrt{2}}$$

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For R

$$\boxed{P = \frac{V_m I_m}{2} = V_{\text{eff}} I_{\text{eff}}} \qquad \text{(W)}$$

$$I_{\text{eff}} = \frac{V_{\text{eff}}}{R}$$

$$\boxed{P = \frac{V_{\text{eff}}^2}{R} = I_{\text{eff}}^2 R} \qquad \text{(W)}$$

For L and C

The average power or power dissipated by the ideal inductor (no associated resistance) is zero watts.

The average power or power dissipated by the ideal capacitor (no associated resistance) is zero watts.

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Thanks

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