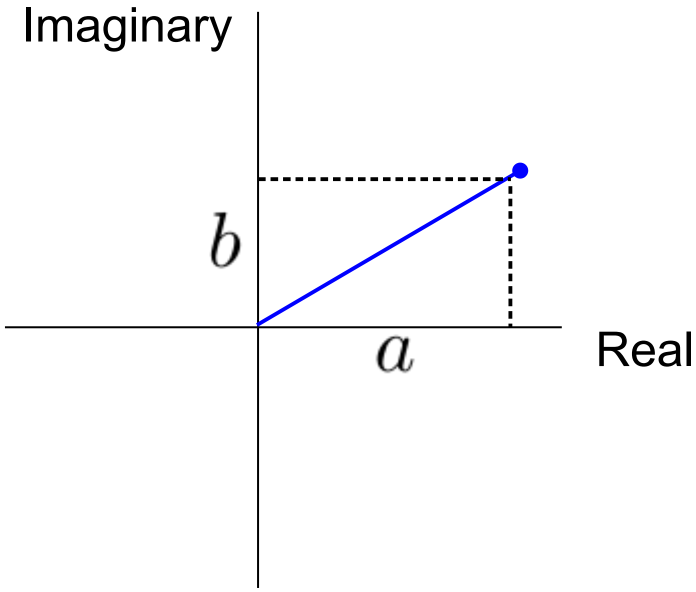
Lab 3: Capacitors and Inductors in AC circuits

Review of Complex Numbers

$$j = \sqrt{-1}$$

$$z = a + jb$$



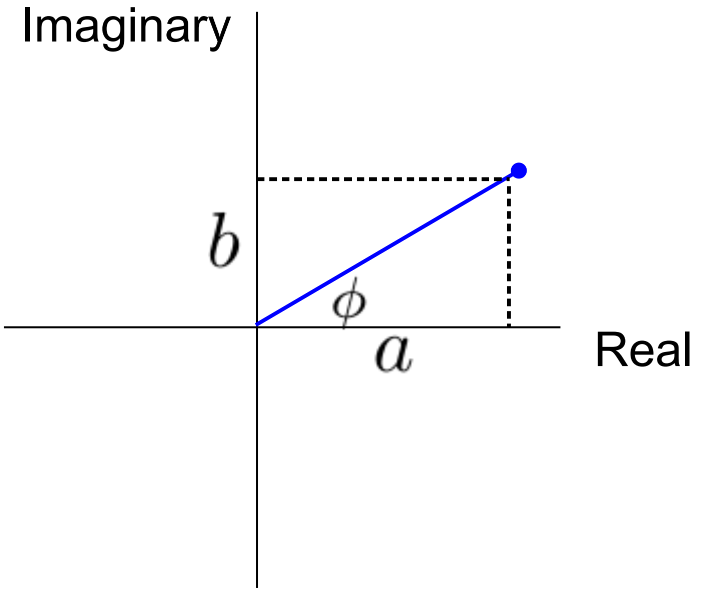
Review of Complex Numbers

$$j = \sqrt{-1}$$

$$z = a + jb = Ae^{j\phi}$$

Amplitude $$A = \sqrt{a^2 + b^2}$$

Phase $$\phi = \tan^{-1}\left(\frac{b}{a}\right)$$



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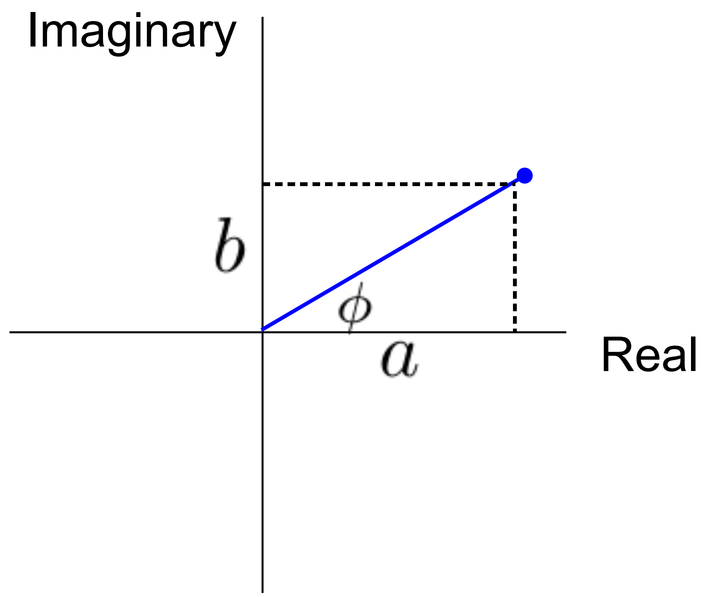


Phaseshift

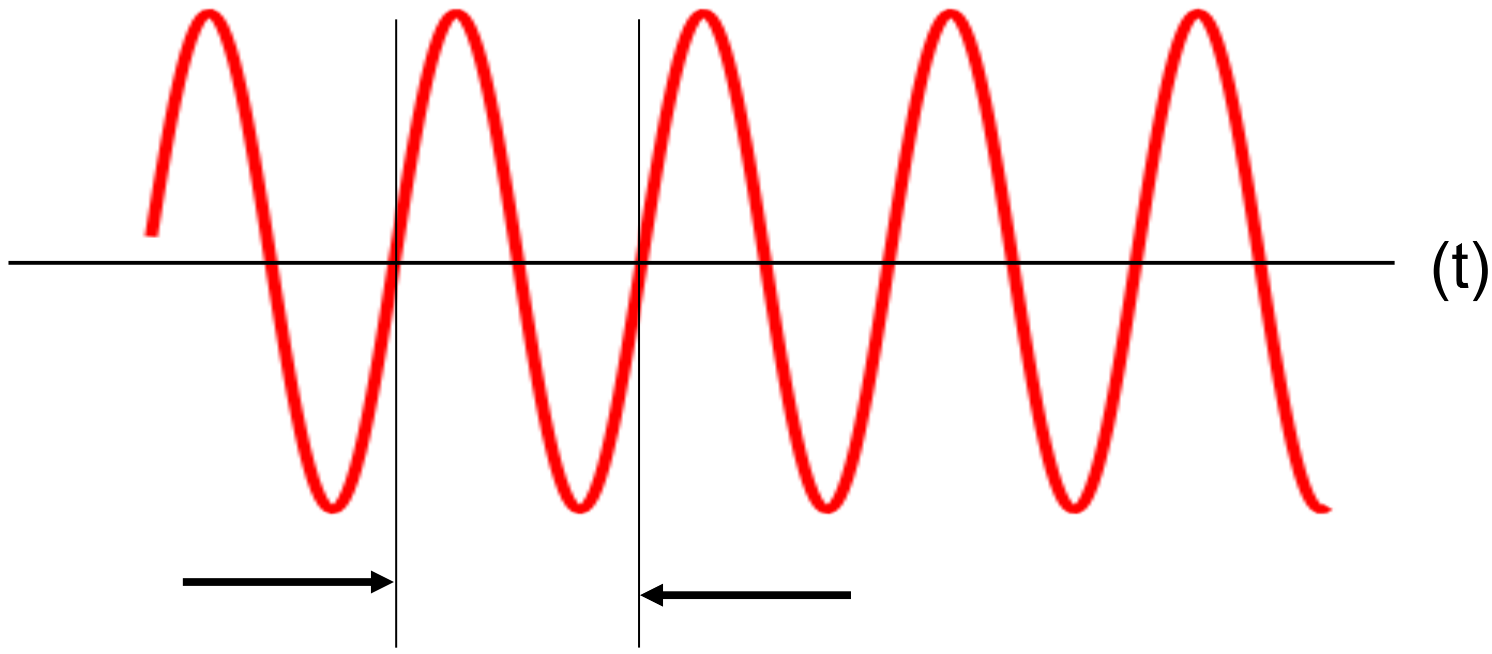
$$e^{j\phi} = \cos\phi + j\sin\phi$$

$$e^{j\frac{\pi}{2}} = \cos(\tfrac{\pi}{2}) + j\sin(\tfrac{\pi}{2}) = j$$

OUR ESSENTIAL WORKING ASSUMPTION:

AC ≡ **SINUSOIDAL FUNCTION**

$$V(t) = A\sin(\omega t + \phi)$$



T: *Period*

Frequency: **f** = 1/**T**

Capacitor in AC circuit

$$V_{ac} = V_o \sin \omega t$$

$$\omega = 2\pi f$$

ω : radians/sec
f: Herz (1/sec)

Capacitor in AC circuit

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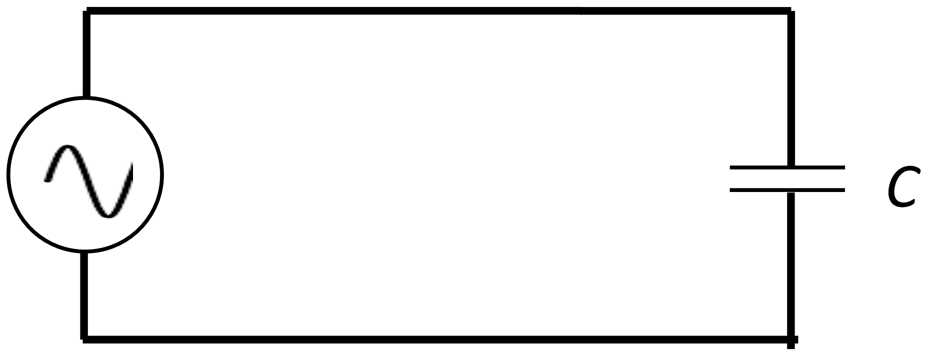
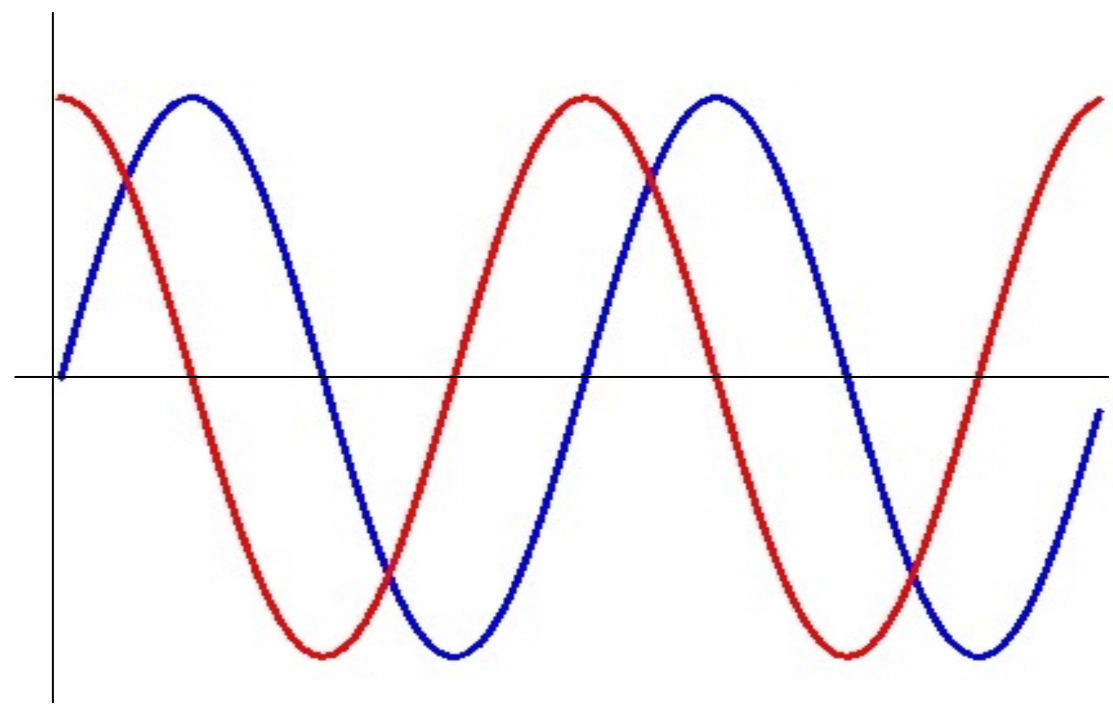


$$\omega = 2\pi f$$

ω : radians/sec
f: Herz (1/sec)

$V(t) = V_0 \sin(\omega t + \phi_0)$ **VOLTAGE**

$I(t) = I_0 \sin(\omega t + \phi_1)$ **CURRENT**



Inductor in AC circuit

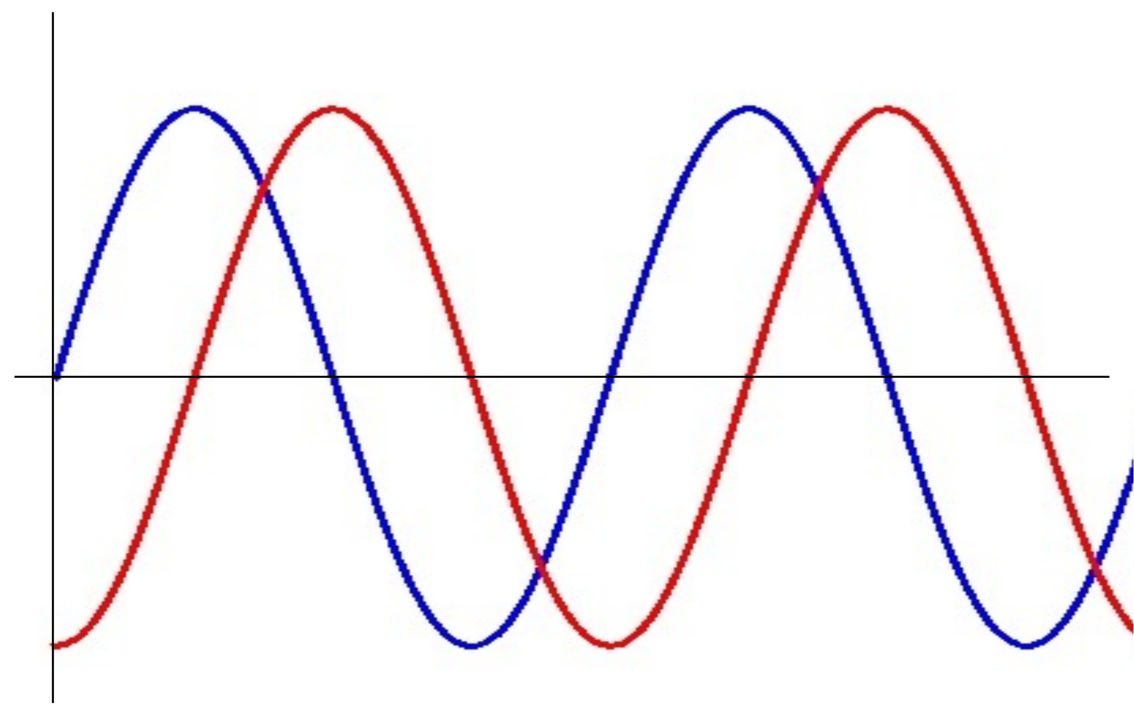
$$V_{ac} = V_o \sin \omega t$$

Inductor in AC circuit

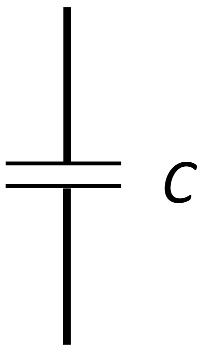
$$V_{ac} = V_o \sin \omega t$$

$V(t) = V_0 \sin(\omega t + \phi_0)$ **VOLTAGE**

$I(t) = I_0 \sin(\omega t + \phi_1)$ **CURRENT**



Ohm's Law for L and C:
Impedance (*Z*)

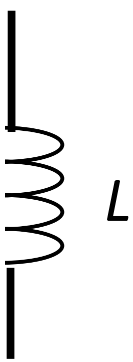


$(Q = CV)$

$$Z_C = \frac{V_C}{I_C} = \frac{V_o \sin \omega t}{\omega C V_o \cos \omega t} = \frac{V_o \sin \omega t}{\omega C V_o \sin \left(\omega t + \frac{\pi}{2}\right)}$$

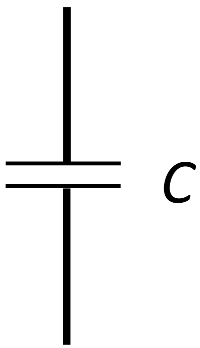
$$V(t) = V_0 \sin(\omega t + \phi_0)$$

$$I(t) = I_0 \sin(\omega t + \phi_1)$$



$(V = L\, dI/dt)$

Ohm's Law for L and C: Impedance (Z)



$(Q = CV)$

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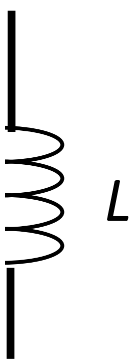
$$V(t) = V_0 \sin(\omega t + \phi_0)$$

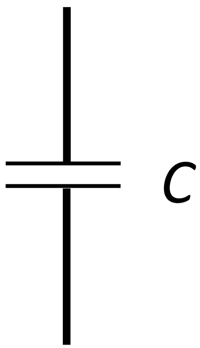
$$I(t) = I_0 \sin(\omega t + \phi_1)$$



$(V = L\, dI/dt)$

$$Z_L = \frac{V_L}{I_L} = \frac{V_o \sin \omega t}{-(V_o/\omega L) \cos \omega t} = \frac{V_o \sin \omega t}{-(V_o/\omega L) \sin\left(\omega t + \frac{\pi}{2}\right)}$$

Ohm's Law for L and C:
Impedance (*Z*)



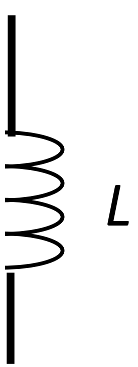
$(Q = CV)$

$$Z_C = \frac{V_C}{I_C} = \frac{V_o \sin \omega t}{\omega C V_o \cos \omega t} = \frac{V_o \sin \omega t}{\omega C V_o \sin\left(\omega t + \frac{\pi}{2}\right)}$$

90° phase shift

$V(t) = V_0 \sin(\omega t + \phi_0)$

$I(t) = I_0 \sin(\omega t + \phi_1)$

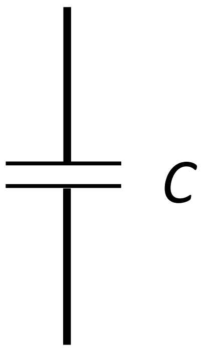


$(V = L\, dI/dt)$

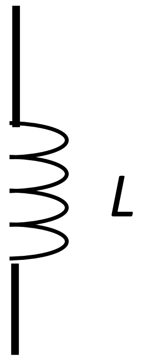
$$Z_L = \frac{V_L}{I_L} = \frac{V_o \sin \omega t}{-(V_o/\omega L)\cos \omega t} = \frac{V_o \sin \omega t}{-(V_o/\omega L)\sin\left(\omega t + \frac{\pi}{2}\right)}$$

90° phase shift

Ohm's Law for L and C:
Impedance (*Z*)



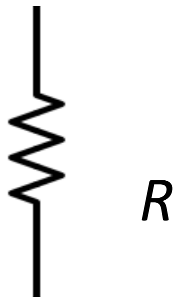
$$Z_C = \frac{V_C}{I_C} = \frac{1}{j\omega C}$$



$$Z_L = \frac{V_L}{I_L} = \frac{\omega L}{-j} = j\omega L$$

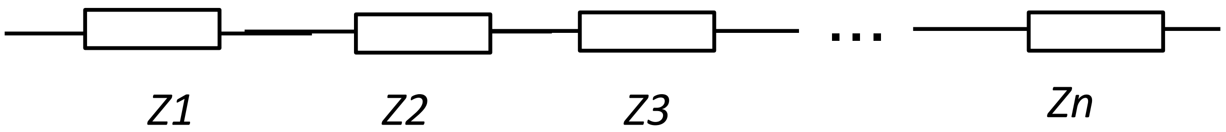
90º phase-shift in polar form: $e^{j\frac{\pi}{2}} = \cos(\frac{\pi}{2}) + j\sin(\frac{\pi}{2}) = j$

Impedance of a Resistor:

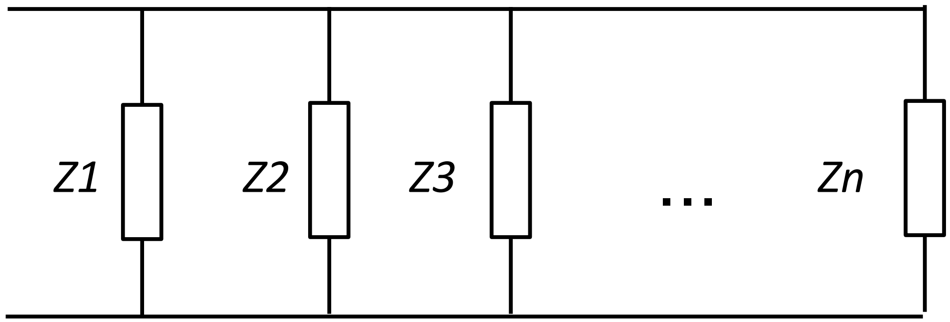


$$Z_R = \frac{V_R}{I_R} = R$$

Impedance arithmetic: same as a resistor

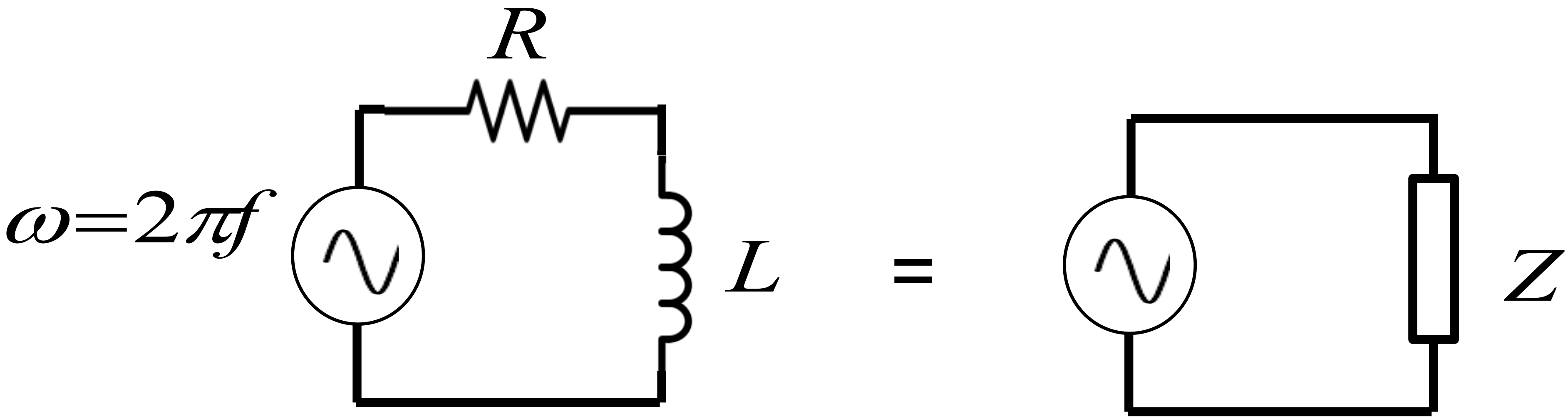


$$Z_{total} = \sum_{i}^{n} Z_i$$



$$\frac{1}{Z_{total}} = \sum_{i}^{n} \frac{1}{Z_i}$$

EXAMPLE 1



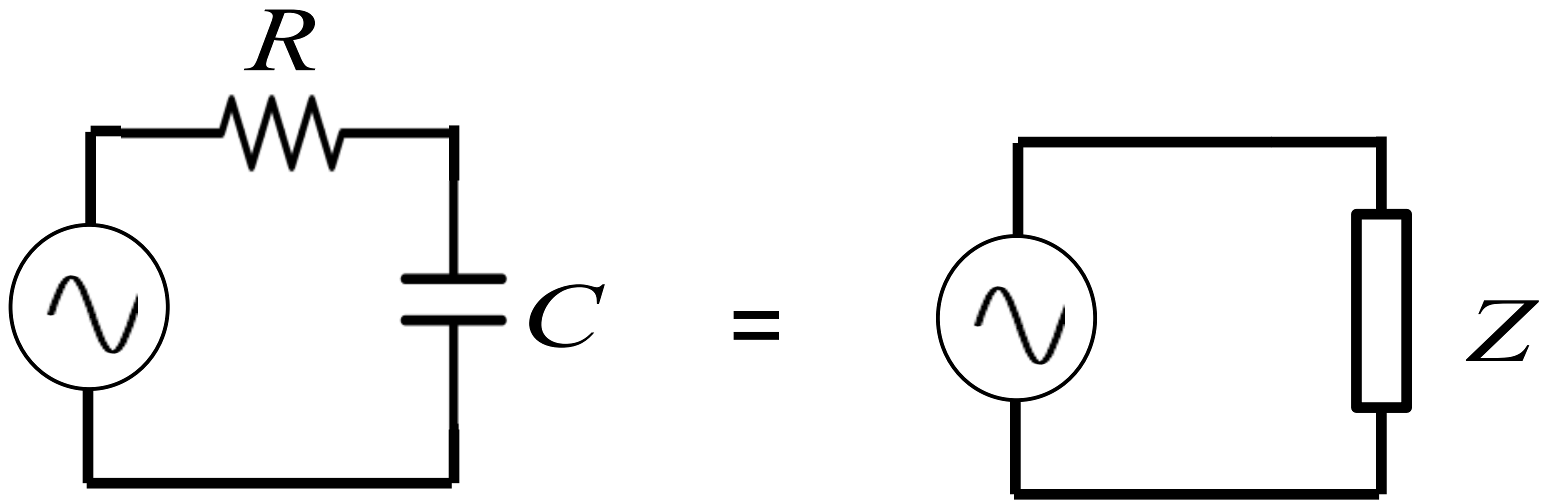
$$Z = Z_R + Z_L = R + j\omega L$$

Resistance (R)

Reactance ($j\omega L$)

EXAMPLE 2

$$\omega = 2\pi f$$

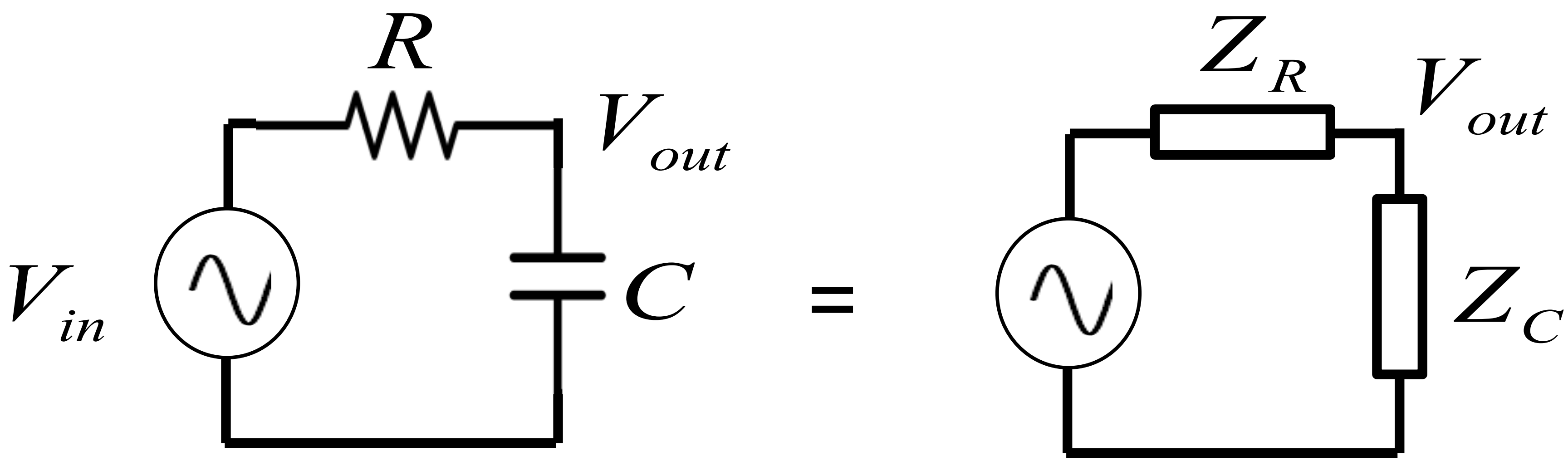


$$Z = Z_R + Z_L = R - \frac{j}{\omega C}$$

Resistance

Reactance

EXAMPLE 3: Voltage Divider

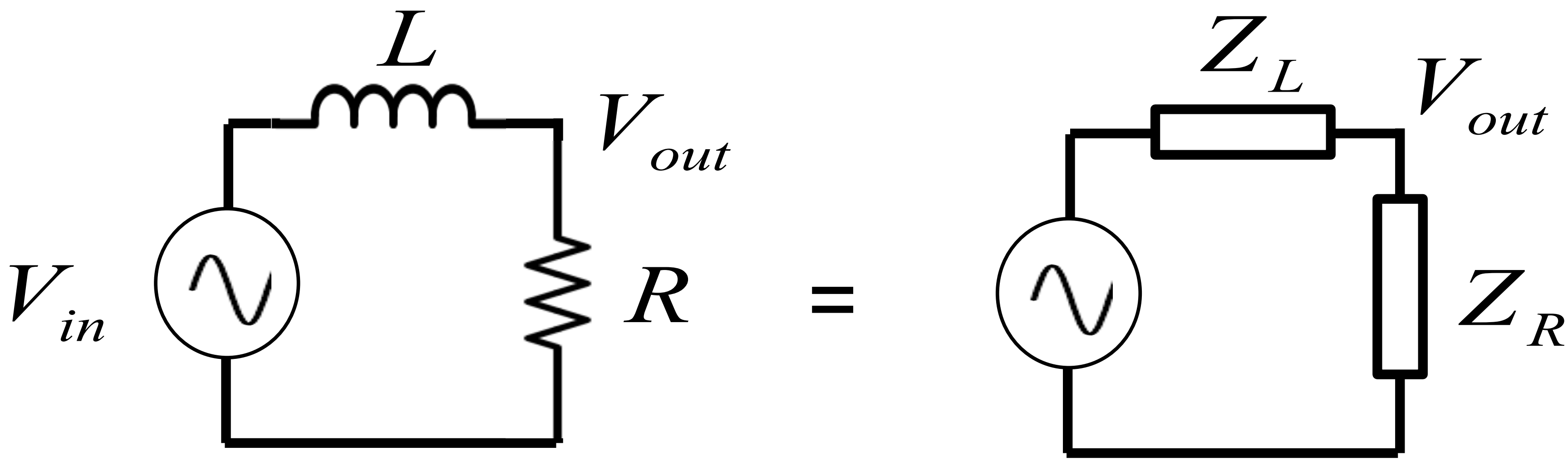


$$\frac{V_{out}}{V_{in}} = \frac{Z_C}{Z_R + Z_C} = \frac{1/j\omega C}{R + 1/j\omega C} = \frac{1}{1 + j\omega RC}$$

$V_{in}(t) = V_0^{in}\,\mathrm{n}(\omega t + \phi_0)$

$V_{out}(t) = V_0^{out}\sin(\omega t + \phi_1)$

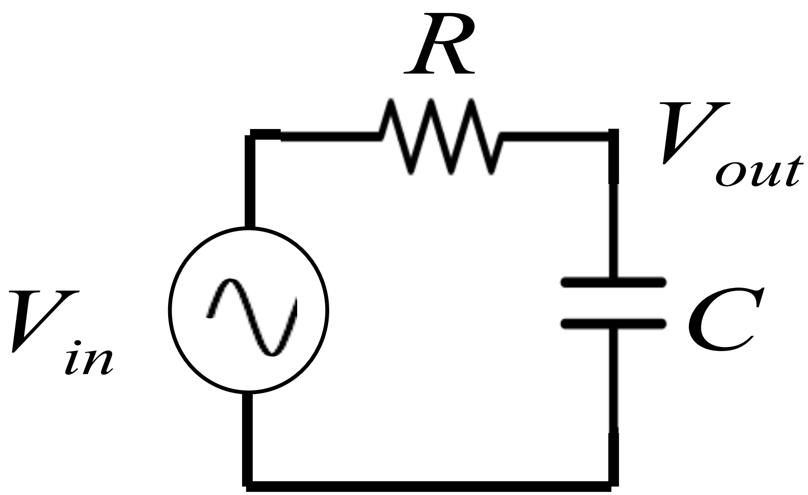
EXAMPLE 4: Voltage Divider



$$\frac{V_{out}}{V_{in}} = \frac{Z_R}{Z_R + Z_L} = \frac{R}{R + j\omega L} = \frac{1}{1 + j\omega L/R}$$

$$V_{in}(t) = V_0^{in}\,\mathrm{n}(\omega t + \phi_0)$$

$$V_{out}(t) = V_0^{out}\sin(\omega t + \phi_1)$$



R = 217.8 Ω
C = 145.6 nF