Announcements:

1. Announcement

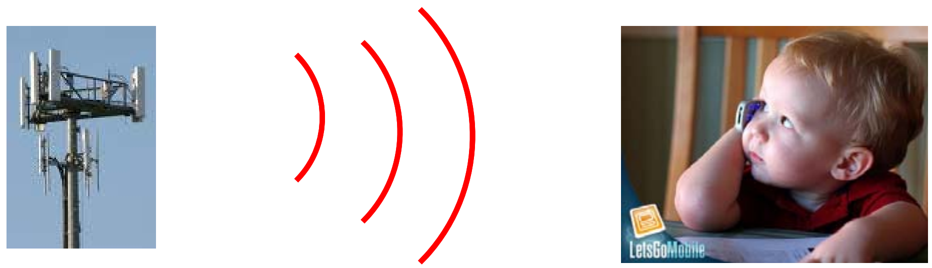
EECS 70A: Network Analysis

Lecture 13

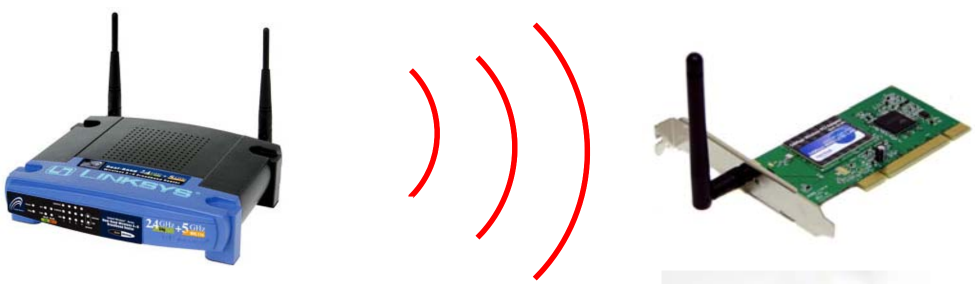
Wireless Communications

Broadcast Radio:

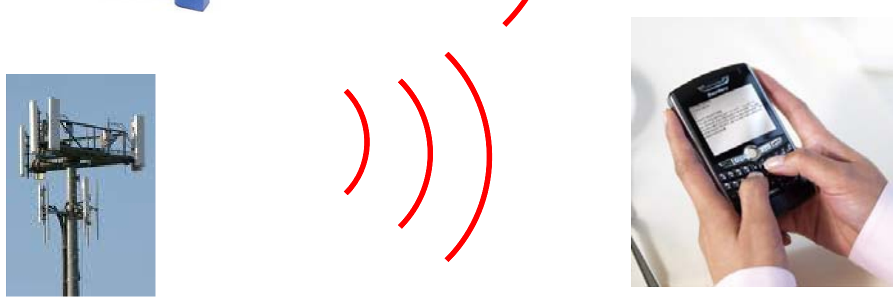
Telecom:



Internet:

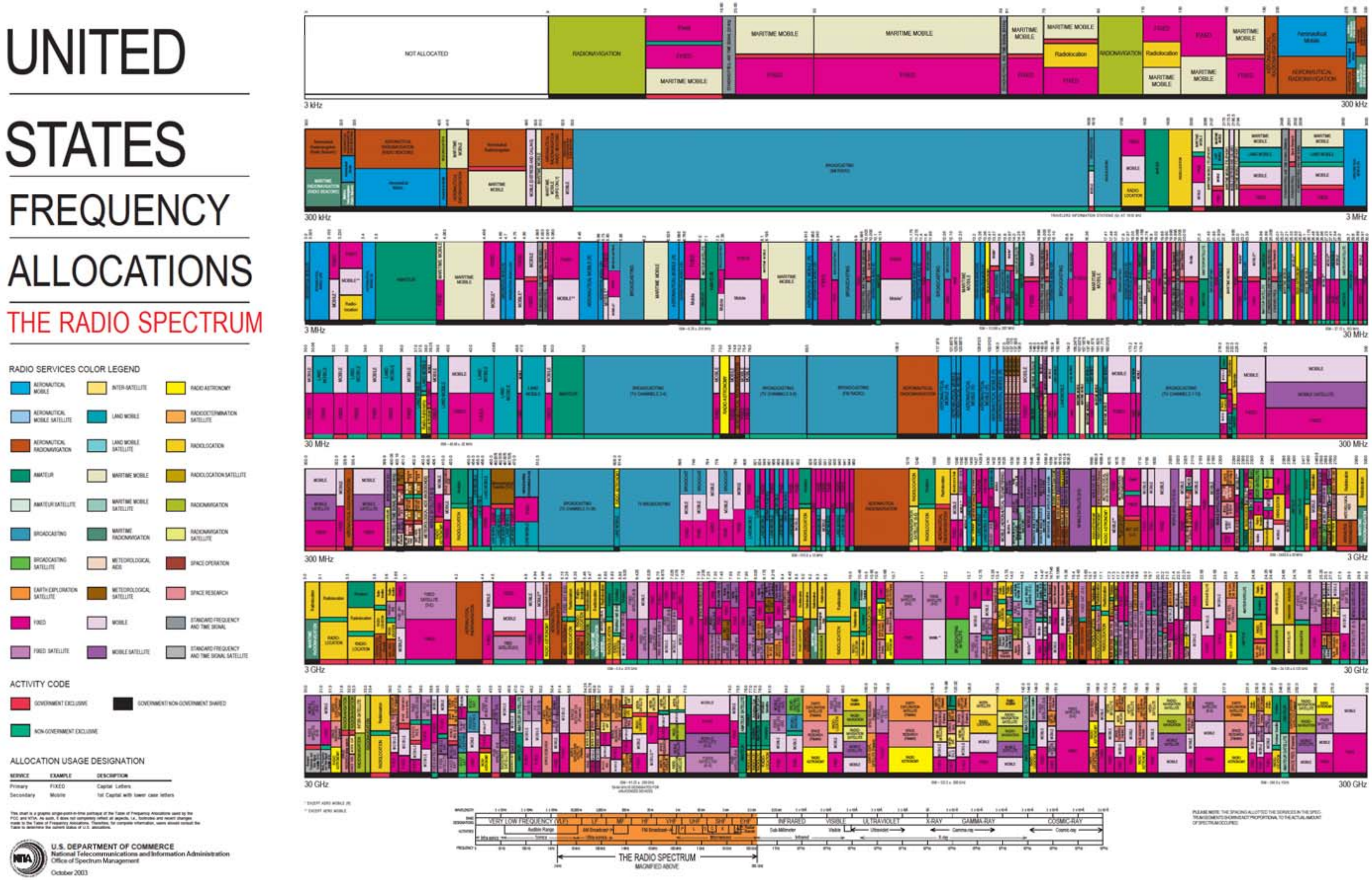


3G data:



All use sine waves (phasors) as way to describe signals and circuits.

Frequency Allocations



http://www.ntia.doc.gov/osmhome/allochrt.PDF

Phasors

$$V(t) = V_m \cos(\omega t + \phi) = \mathrm{Re}\left(V_m e^{j(\omega t + \phi)}\right)$$

$$= \mathrm{Re}\left(\underbrace{V_m e^{j\phi}}_{} e^{j\omega t}\right)$$

"Voltage Phasor" $\mathbf{V}$

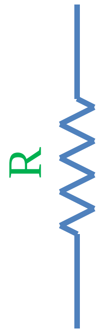
(Complex #)

$$i(t) = I_m \cos(\omega t + \phi) = \mathrm{Re}\left(I_m e^{j(\omega t + \phi)}\right)$$

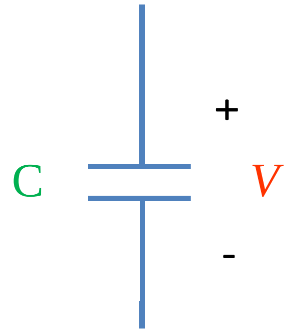
$$= \mathrm{Re}\left(\underbrace{I_m e^{j\phi}}_{} e^{j\omega t}\right)$$

"Current Phasor" $\mathbf{I}$

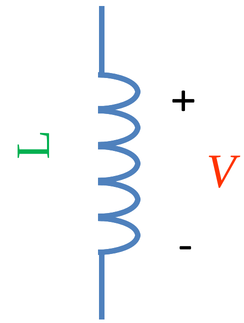
Circuits



$\mathbf{V} = \mathbf{I}\,R$



$\mathbf{V}=\mathbf{I}/j\omega C$



$\mathbf{V}=j\omega L\,\mathbf{I}$

“Impedance”

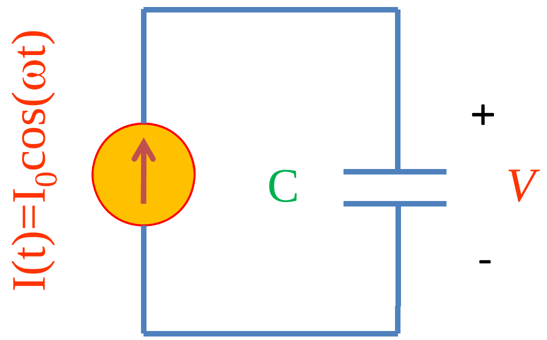
$Z = R$ $\qquad$ $Z=1/j\omega C$ $\qquad$ $Z = j\omega L$

Can think of this as a “generalized Ohm’s law for ac circuits”

KCL, KVL hold for relationship between **V**, **I**.

Phasor to voltage conversion

Find V(t), q(t)



Problem gives us:

$I(t)=I_0\cos(\omega t)$

Compare to definition of current phasor:

$$i(t) = I_m \cos\left(\omega t + \phi\right) = \mathrm{Re}\left(I_m e^{j\phi} e^{j\omega t}\right) = \mathrm{Re}\left(\mathbf{I} e^{j\omega t}\right)$$

$$\Rightarrow \mathbf{I} = I_0$$

Find voltage phasor using generalized Ohm's law:

$$\mathbf{V}=\mathbf{I}/j\omega C$$

Find v(t) from voltage phasor:

$$v(t) = \mathrm{Re}\left[\mathbf{V} e^{j\omega t}\right] = \mathrm{Re}\left[\left(\frac{\mathbf{I}}{j\omega C}\right) e^{j\omega t}\right] = \mathrm{Re}\left[\left(\frac{I_0}{j\omega C}\right) e^{j\omega t}\right]$$

$$= \frac{I_0}{\omega C}\mathrm{Re}\left[\left(\frac{1}{j}\right) e^{j\omega t}\right] = \frac{I_0}{\omega C}\mathrm{Re}\left[-j e^{j\omega t}\right] = \frac{I_0}{\omega C}\mathrm{Re}\left[-j\left(\cos(\omega t) + j\sin(\omega t)\right)\right]$$

$$= \frac{I_0}{\omega C}\mathrm{Re}\left[-j\cos(\omega t) + (-j)j\sin(\omega t)\right] = \frac{I_0}{\omega C}\mathrm{Re}\left[\sin(\omega t) - j\cos(\omega t)\right] = \frac{I_0}{\omega C}\sin(\omega t)$$

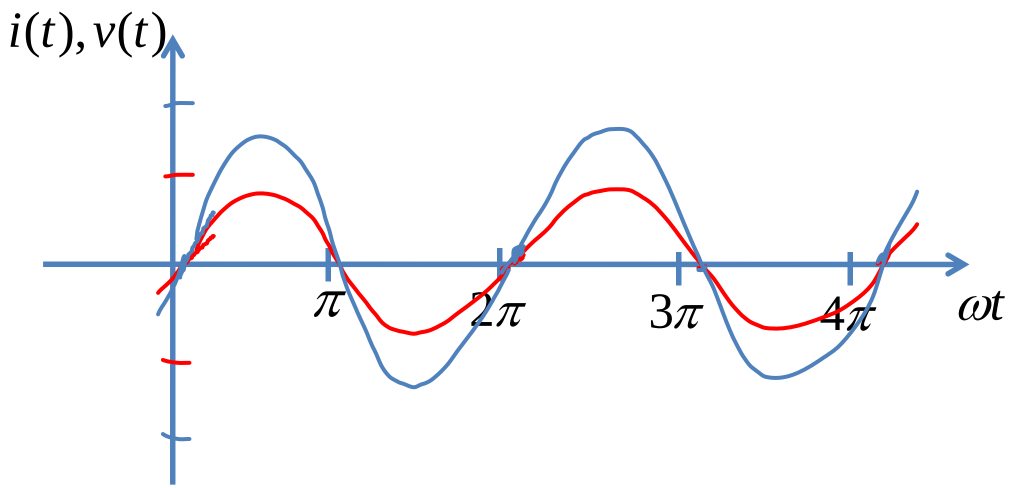
Phase vs. impedance (Z)

In general:

Z real i.e. Z = x + jy

$\neq 0$ (x) $= 0$ (y)

=> i(t), v(t) "in phase"

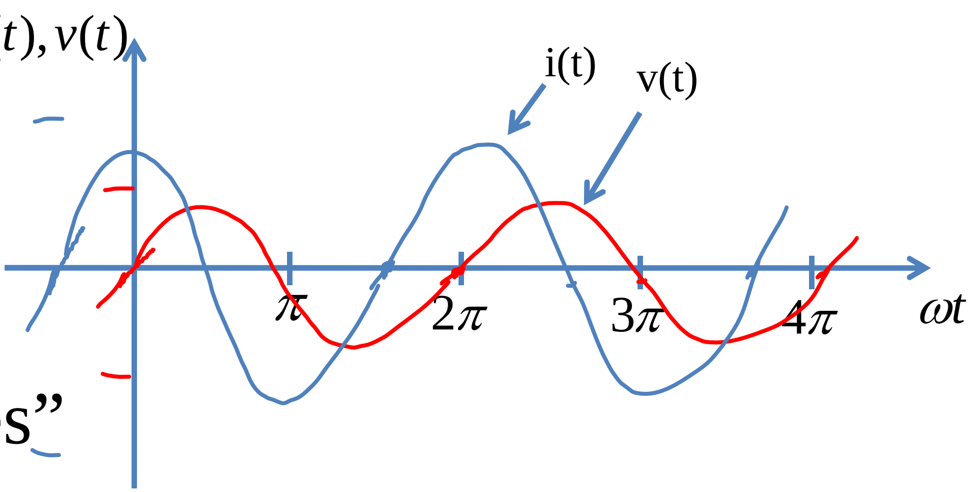


In general:

Z imag i.e. Z = x + jy

$= 0$ (x) $\neq 0$ (y)

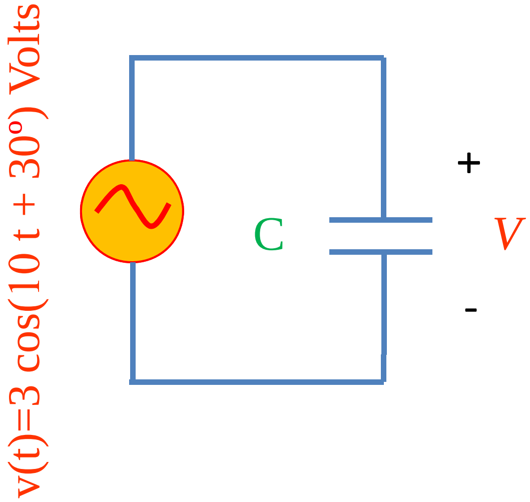
=> i(t), v(t) "out of phase
by 90 degrees"



HW problem: Find relationship between phase shift and impedance (Z).

Example phasor problem

Find i(t) (students)



Problem gives us:

v(t)=3 cos(10 t + 30º) Volts

Compare to definition of voltage phasor:

$$v(t) = V_m \cos\left(\omega t + \phi\right) = \mathrm{Re}\left(V_m e^{j\phi} e^{j\omega t}\right) = \mathrm{Re}\left[\mathbf{V} e^{j\omega t}\right]$$

$$\Rightarrow \mathbf{V} = ?$$

Find current phasor using generalized Ohm's law:

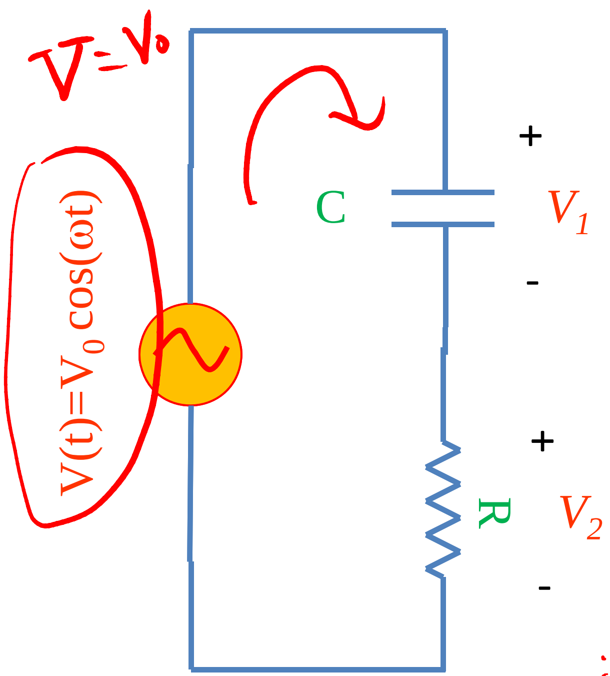
$$\mathbf{I} = j\omega C\, \mathbf{V} = \ldots$$

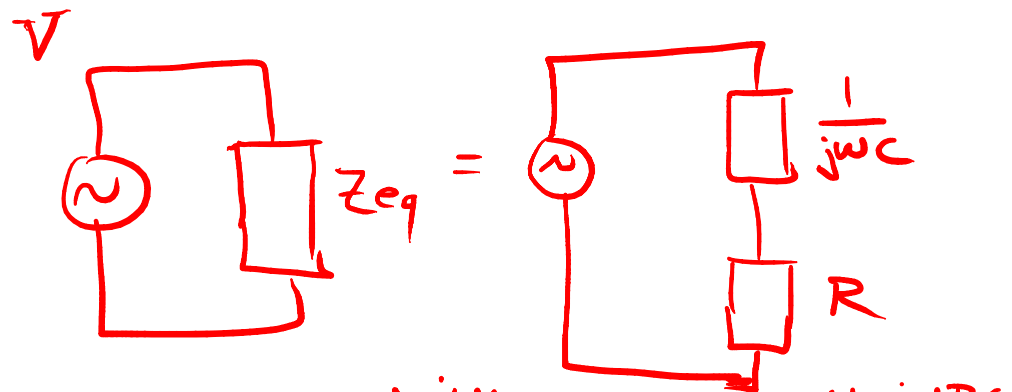
Find i(t) from current phasor:

$$i(t) = \mathrm{Re}\left(\mathbf{I} e^{j\omega t}\right) = \ldots$$

Example problem #3

Find i(t), $V_1(t)$, $V_2(t)$ for this circuit: (instructor)





$$Z_{eq} = \left(R + \frac{1}{j\omega C}\right)\frac{j\omega C}{j\omega C} = \frac{1 + j\omega RC}{j\omega C}$$

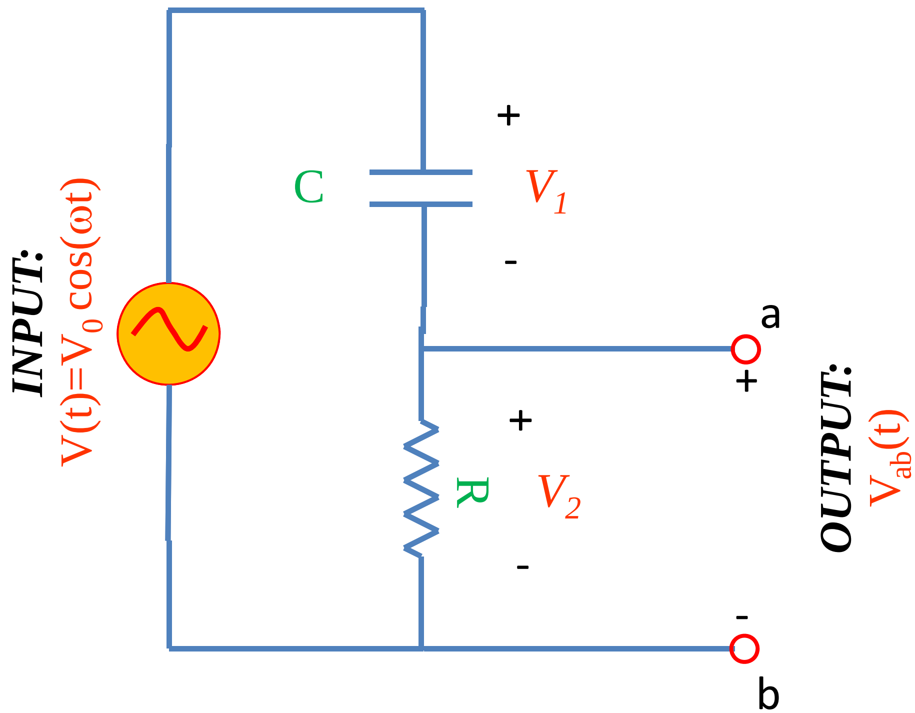
$$V = Z_{eq} I \Rightarrow I = \frac{V}{Z_{eq}}$$

$$i(t) = Re\left[I e^{j\omega t}\right] = Re\left[\frac{V}{Z_{eq}} e^{j\omega t}\right]$$

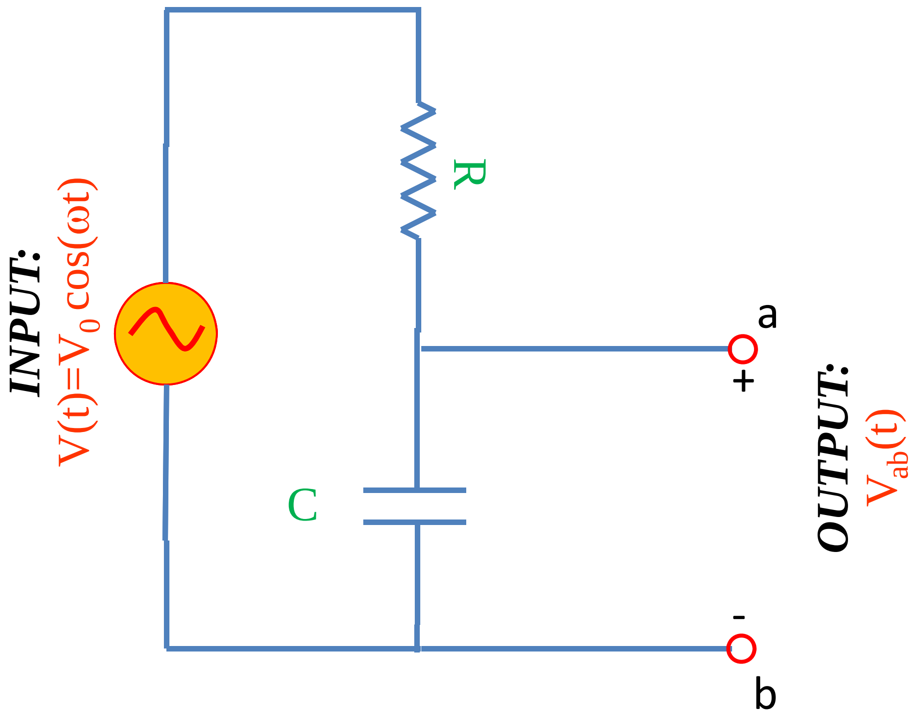
$$= Re\left[\frac{V_0}{R + (j\omega C)^{-1}} e^{j\omega t}\right] = Re\left[\frac{V_0\, j\omega RC}{1 + j\omega RC} e^{j\omega t}\right]$$

$\cos\omega t + j \sin\omega t$

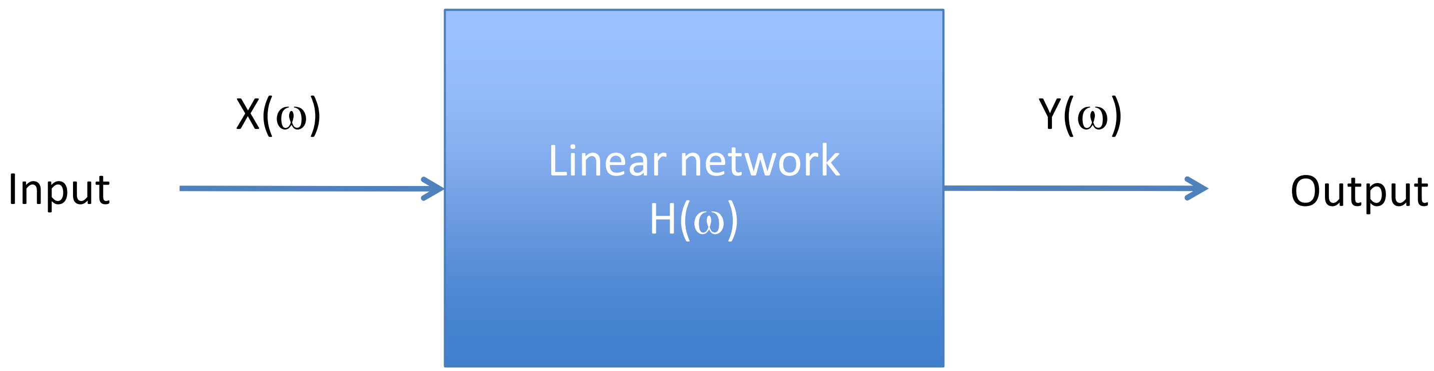
High pass filter



Low pass filter

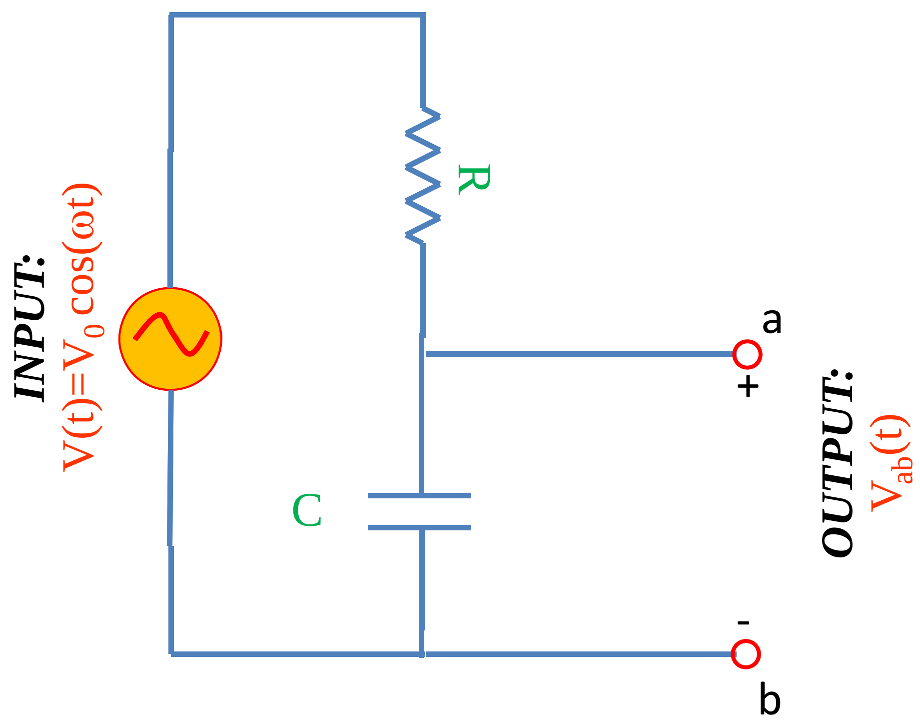


“Transfer function”



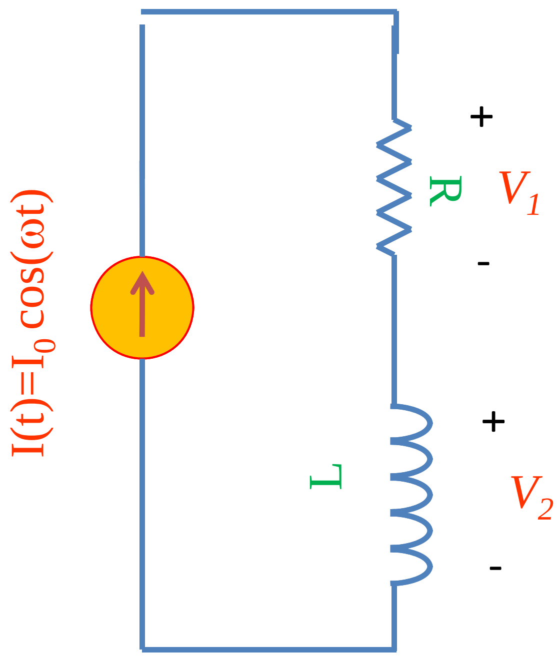
demo

RC transfer function

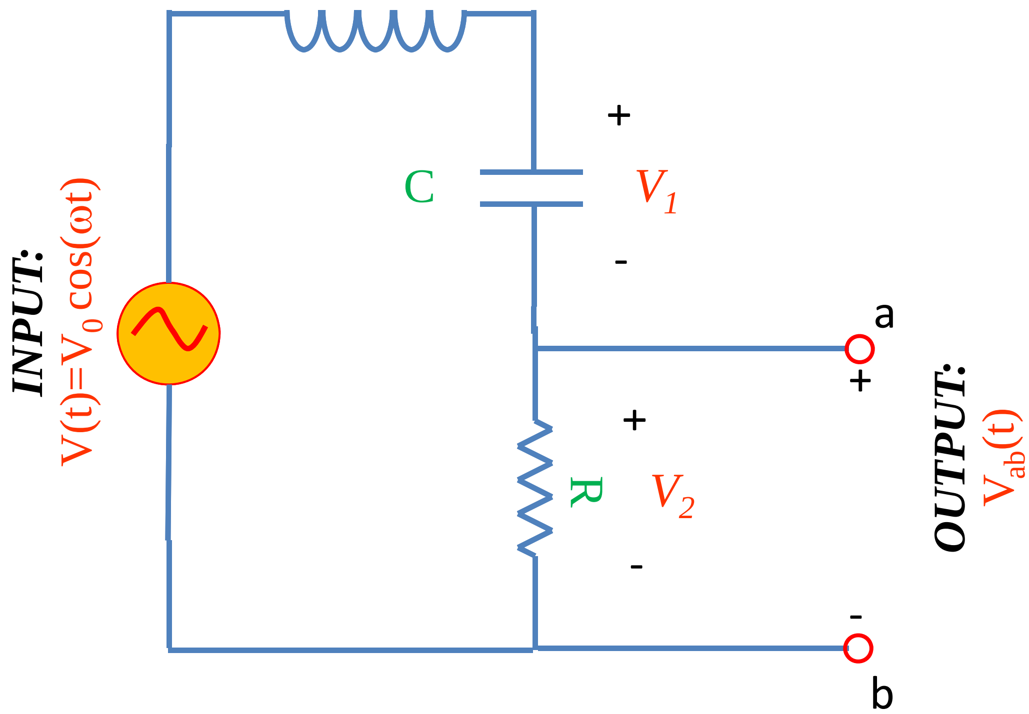


Example problem #4

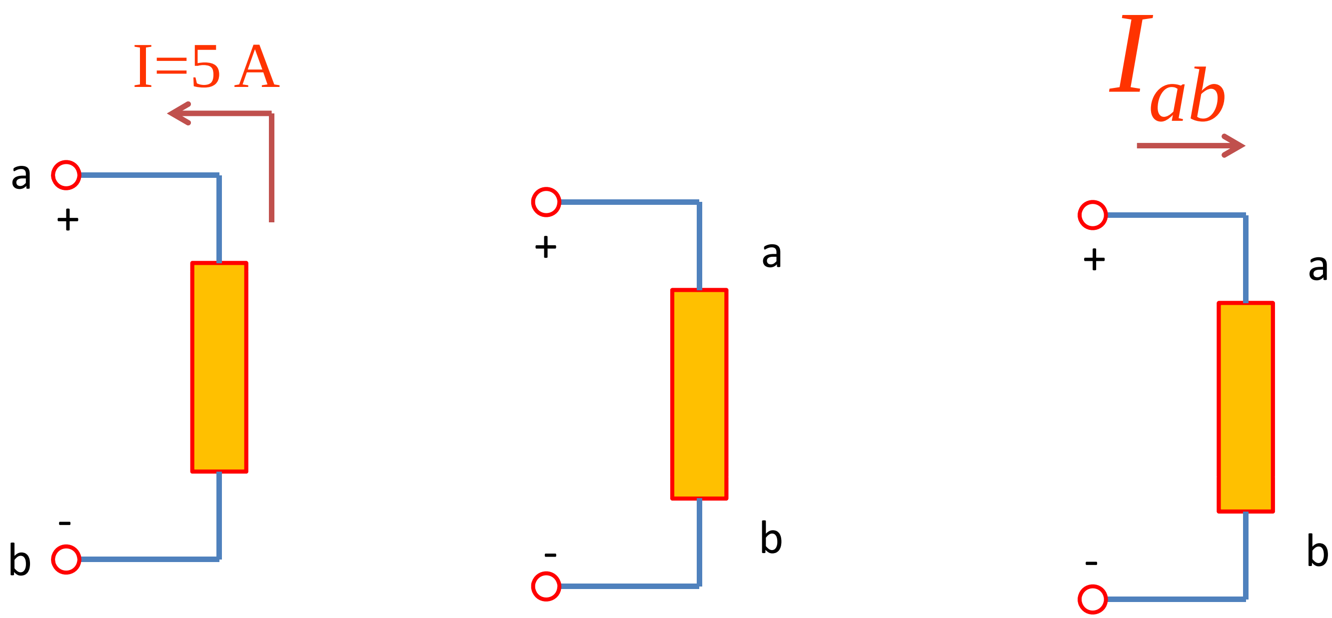
Find i(t), V_1(t), V_2(t) for this circuit: (students)



Band pass filter (RLC)



Symbol library



Symbol library